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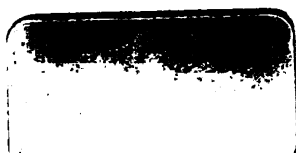
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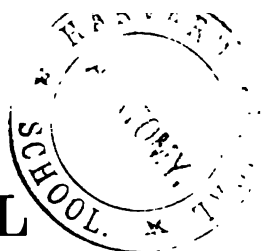
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Journal of Anatomy and Physiology.

THE SIGNIFICANCE OF ANATOMICAL VARIATIONS.

By D. J. CUNNINGHAM, F.R.S.¹

IN dealing with a subject so wide and of such far-reaching significance as that of '*Anatomical Variations*,' I feel that it is necessary at the very outset to indicate the ground on which I purpose to take my stand, and to set some limitation upon the scope of my remarks.

In the first instance, let me lighten my cargo by throwing overboard '*Acquired Variations*.' I do so reluctantly, but with the declared intention of thereby evading the necessity of entering into the vexed question of the transmission of acquired characters.

Of the variations in structure which remain, a very large number may be placed in one of two categories, viz., those which point backwards and those which point forwards, or, to put it in other words, those which relate to the past and those which indicate the possibilities of the future. For want of better terms, we may call these two kinds of variations *Retrospective* and *Prospective*. It is with such variations alone that I intend to deal. Retrospective variations act as sign-posts, planted at very irregular intervals, and often appearing at very unexpected places, which indicate the path which the individual has traversed in his ontogenetic and phylogenetic development. Prospective variations afford evidence, often most uncertain, almost always vague and faltering, which gives us some inkling of the direction towards which phylogenetic evolution is tending.

¹ Opening statement at the discussion on the "Significance of Anatomical Variations," held in the Anatomy Section of the British Medical Association in Edinburgh, July 1898.

RETROSPECTIVE VARIATIONS.

Retrospective variations may be separated into two classes which touch each other at their boundaries, and which not unfrequently overlap. I refer to—

1. Simple ontogenetic arrests.
2. Atavism, or progonism.¹

Ontogenetic Arrests.—A simple arrest in the natural course of ordinary individual development may present little morphological interest, or it may be fraught with the most important and deep-lying significance. This difference depends chiefly upon the relation which such variations bear to the evolutionary history of the individual. Thus, an ectopia vesicæ, or an imperforate anus, although each possesses a very special intrinsic interest of its own, cannot claim rank as variations which throw light upon ancestral history; and the morphological importance of a variation is tested from this standpoint.

I presume that most of us are believers in the recapitulation theory, and hold that, to some extent at least, an animal reveals its pedigree in the successive stages of its own development. In their relation to ancestral history, some of these developmental stages are more important than others. This is particularly the case where a stage is reached which represents a point of departure in structural detail from other animal groups which have accompanied the individual in question so far on the phylogenetic path.

These are 'critical periods' in individual development, and an arrest at such a stage may lead to very striking results. Such a critical period occurs in the development of the primate cerebrum between the third and fourth months of foetal life. About this time the cerebrum takes that step which lifts it beyond the quadrupedal stage and places it upon the higher primate platform. Previous to this change the cerebrum presents a form similar to that of a quadruped; but now the occipital lobe takes shape, and the cerebrum assumes a form and an outline which are characteristic of man and the apes, and of them alone.

¹ An alternative term suggested by Professor Mahaffy.

This is a great advance in cerebral development, and the period at which it occurs is a very natural one for a disturbance of the normal process to take place. Old tendencies, dormant it may be, but capable of being stirred into activity by some unknown cause, counteract the more recently-acquired tendencies towards a higher cerebral development, and a defective occipital lobe is the result. This is a leading peculiarity of one form of microcephalic brain, and it expresses in the clearest manner a tendency on the part of the cerebrum to cling to its old quadrupedal traditions, and to lag behind when, in the process of development, it has reached the quadrupedal stage.

Atavism, or Progonism.—Retrospective variations of the atavistic type are much more difficult to determine and correctly appreciate. At the same time, they are, as a rule, of greater importance than simple developmental arrests, seeing that in every case they have a direct relation to the ancestral history of the individual. The term 'atavism' is employed in different senses by different writers. It is requisite, therefore, that I should define the precise meaning I wish to convey. "Although it is undoubtedly true," writes Milnes Marshall, "that development is to be regarded as a recapitulation of ancestral phases, and that the embryonic history of an animal presents to us a record of the race history, yet it also is an undoubted fact, recognised by all writers on embryology, that the record so obtained is neither a complete nor a straightforward one. It is indeed a history, but a history of which entire chapters are lost; while in those that remain, many pages are misplaced, and others so blurred as to be illegible."

In a simple arrest of development, an embryonic condition, which is normally transient, becomes, as it were, set and crystallised; but this does not necessarily imply that the phase which is produced is one which, at any previous period in the phylogenetic history of the individual, was characteristic of the stem-form. Something more is required to constitute a case of atavism. It is necessary that certain of those ancestral features which are omitted in the ordinary course of individual development should be reproduced, or that certain of those parts of the phylogenetic history which have become blurred or abbreviated

in the ontogeny of the individual should reappear in a distinct and an intelligible manner.

The best example that I can offer of what has appeared to me to be a plain case of atavistic variation is the convolutionary pattern which is assumed by the cerebral surface in certain forms of microcephalism. The convolutions and sulci on the brain of a microcephalic idiot may assume an arrangement which approaches more closely to the ape-type than the man-type; and the significant point is that, in these cases, there is a mixture of those characters which are distinctive of a high ape with those which are characteristic of a low ape. The general arrangement may differ widely from that seen in the brain of any one ape; but it presents certain features which are peculiar to an anthropoid, and others which are characteristic of, say, a baboon or a macaque. From this we conclude that, in so far as its convolutionary arrangement is concerned, the brain has reverted wholly or in part to a condition which existed previously in an early stem-form. I hardly think that it could be argued that the microcephalic idiot has pursued an independent development along a line of its own from the point of divergence of the high and low apes, and midway between them.

Whether the brain of a microcephalic idiot ever repeats in its totality the convolutionary pattern which was distinctive of any particular period in the history of the stem-form it is impossible to say, but I am rather inclined to think that such an occurrence is extremely unlikely. Still, I have in my possession a microcephalic brain, with a convolutionary arrangement so consistent in its pattern that I cannot shut my eyes to the possibility that in it we may have a tolerably faithful reproduction of the gyri and sulci which were at one time characteristic of an early stem-form of man,

It has become too much the custom to place all anomalies of the muscular system in the atavistic group. Many, no doubt, are atavisms, and these, as a rule, are fairly easy to determine; but Macalister, our greatest authority on this subject, rightly protests against what he properly terms the "purely gratuitous assumption" that every muscular anomaly is a retrospective variation.

Some parts of the body are much more liable to atavistic

variations than others; and it may be laid down as a general proposition, the truth of which must have struck every one who has given the matter serious consideration, that stability of structure is a character of those organs which have a long ancestral history, whilst instability of structure is characteristic of those with a short ancestral history. Thus, phylogenetically old parts are not, as a rule, liable to variation, whilst parts which are of comparatively recent phylogenetic origin are very prone to variation. In the former, oscillation has, to a large extent, stopped, and a measure of equilibrium has been obtained; in the latter, the oscillations both backwards and forwards are going on, even although the mean position may, in a measure, have been determined.

In no animal can the truth of this statement be more satisfactorily proved than in man. He is the proud and sole possessor of the erect attitude. The acquisition of this, at no distant period in his ancestral history, has profoundly disturbed his whole anatomy, and is largely responsible for many of the variations which are so abundantly and so frequently met with in his structure.¹

A variation may occur in man which produces a structural character identical with what is seen normally in another animal group. The variation *may be* truly atavistic, but for all that it does not follow, as a matter of course, that it is genetically related to the corresponding character in the animal group. In two groups of animals which have separated from each other low down in the genealogical tree development may go on along parallel tracks, and characters which are similar may be produced in either quite independently of each other. This possibility has always to be borne in mind in determining the proper value of an anatomical variation.

PROSPECTIVE VARIATIONS.

Prospective or Prophetic variation may be termed *Epigonism*—a word which has been suggested to me by Professor Mahaffy, and which seems exactly to suit the case. The law which

¹ Domestication is also said to produce conditions favourable to variation, and the liability to variation exhibited by the structure of man may also, perhaps, in some measure, be due to this.

regulates such variations is absolutely unknown: they appear to be fortuitous, but upon this point we have no sure information. Some of these variations may lead to little or no result; others which tend to adapt the individual more perfectly to its environment are strengthened and perhaps perpetuated by natural selection. The latter are the true cases of epigonism; and, as it will be readily understood, such variations are extremely difficult to determine and to interpret aright. In the case of retrospective variations, we can consult the ancestral record as revealed to us by the facts of comparative anatomy, and we can compare and check the information thus gained by a reference to the developmental history of the individual itself. In the case of epigonism, the aid which is obtained from these sources is of a limited kind: each case must, to a large extent, be judged on its own intrinsic merits, and often under most confusing and misleading circumstances. The difficulties connected with the determination of epigonisms are still further intensified by the fact that it does not necessarily follow that because a variation is in process of being perpetuated, it is what might be considered a structural improvement. It may, indeed, be very much the reverse, and represent a retrograde rather than a forward step. An example of such a character may be found in the progressive blindness in cave-dwelling animals.

As we all know, the lumbo-sacral region of the spine in man is in a state of very unstable equilibrium, and here I believe we may study examples both of retrospective and prospective variation. The normal condition is one in which there are twenty-four movable vertebræ in front of the sacrum, and in which the lower limb is attached to the upper three sacral vertebræ. The variations that occur are of two distinct and opposite kinds:—

1. A complete or incomplete liberation of the first sacral vertebra, and associated with this a slipping back on the vertebral column of the iliac attachment of the lower limb.

2. A partial or complete inclusion of the last lumbar vertebra in the sacrum, and associated with this a slipping forwards on the vertebral column of the iliac attachment of the lower limb.

In the first case, the tendency is towards elongation of the

præsacral part of the spine; in the second, the tendency is towards abbreviation of the præsacral part of the spine.

Professor Paterson, in his elaborate memoir on the Human Sacrum, has given a most masterly analysis of these two different forms of variation, and he has shown, in the most conclusive manner, that the number of cases in which elongation occurs is greater than that in which abbreviation takes place. From this he is inclined to argue that Rosenberg is wrong in considering that the vertebral column of the future will be one in which, in all probability, the præsacral region is shortened by one vertebra.

I am not altogether satisfied that Professor Paterson is justified in coming to this conclusion. A question of this kind cannot be settled by mere statistics. A prophetic or prospective variation is greatly handicapped at the start, and at first it makes little headway against the strong counter-current of normal and atavistic tendencies. A long period of time must elapse before natural selection strengthens and intensifies it sufficiently to enable it to win its way to a high place on the statistical table.

Let us see what the ontogenetic and phylogenetic records have to say on this matter. The developmental evidence is not conclusive on either side; but the ancestral history of man, and those apes most nearly related to him, so far as we know it, seems to me to favour the view of Rosenberg, viz., that there is a progressive tendency in man towards the shortening of the vertebral column.

It is probable that man and the four anthropoid apes have descended from a gibbon-like ancestor (*Prothylobates* of Dubois), and that this stem-form had a vertebral column with at least 26 præsacral vertebræ. In the lower apes of the old world, the number of præsacral vertebræ, with very few exceptions, is 26; in the gibbon, 25 or 24; in man, the gorilla, and the chimpanzee, 24; and in the orang, 23. In the evolution of the higher members of the primate family there appears to be, therefore, a tendency towards the abbreviation of the præsacral part of the vertebral column, and the orang has travelled furthest along this path.

But in the anthropoid ape, as in man, the lumbo-sacral region is very subject to variation. In the orang this is less evident

than in the others. It has reached its goal, and has attained a position of rest, in so far as forward movement of the hind-limb on the spine is concerned. There is a strong atavistic tendency present, however, so that although variations exhibiting further præsaclral abbreviation are extremely uncommon, variations exhibiting elongation are fairly frequent.

In the chimpanzee and the gorilla, variations of abbreviation are more common than variations of elongation (Paterson); and it would seem from this that these apes are following fast on the heels of the orang.

Man, and still more the gibbon, are lagging behind, but both, and more especially man, has made considerable progress along the path which may ultimately lead to the loss of a præsaclral vertebra.¹ These are the facts which have induced me to lean somewhat towards the views of Rosenberg. In connection with this, it is interesting to note, although this is an argument of no anatomical value, that the æsthetic taste of Man emphatically condemns a long trunk and short legs.

Of course, we cannot discuss this matter without taking into account the arrangement of the nerves with reference to the spine and the lower limb. In this matter also we have to fall back on Professor Paterson's paper for information, and from it two points of essential importance can be made out:—

1. It does not necessarily follow that a variation in the arrangement of the nerves coincides with a corresponding variation of the vertebral column, and *vice versa*.

2. That the tendency towards caudad shifting of the hind-limb nerves is much more marked than the tendency towards cephalad shifting.

This is precisely what we would expect, and I do not think that it in any way invalidates Rosenberg's proposition. Nerves are the most conservative of all the structures which go to build up the human body. They cling most tenaciously to old traditions, and travel most pertinaciously along the old beaten paths. In illustration of this, consider the wasting platysma and its large and vigorous nerve of supply; and still more, the interossei muscles in the foot of the horse, which are almost completely

¹ The number of præsaclral vertebrae in the Gibbon is 24 in *Hylobates syndactylus*, and 25 in *Hylobates lar* (Flower).

transformed into ligamentous tissue (suspensory ligament of the fetlock), in the midst of which we have entombed the old nerves of supply still histologically perfect. It is not surprising, therefore, that the lumbo-sacral variations should indicate that in the abbreviation process the more plastic skeleton is a step in advance of the unimpressible nervous system.

From the foregoing it must not be assumed that I consider that Rosenberg's view is by any means established. All I wish to convey is, that I believe that the balance of such evidence as is at our disposal is in favour of his theory. I fully indorse Professor Paterson's remark, that further observations are required on several points before a final conclusion can be arrived at.

A STUDY OF THE ARRANGEMENT OF THE MUSCULAR FIBRES AT THE UPPER END OF THE ŒSOPHAGUS.

By A. BIRMINGHAM, M.D., *Professor of Anatomy, Catholic University, Dublin.*

WITH the current description of the longitudinal muscular fibres at the upper end of the œsophagus, in which these fibres

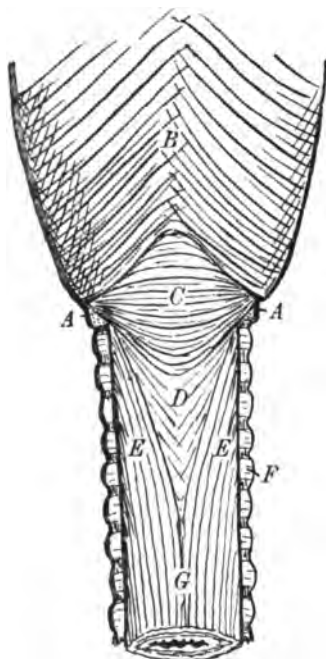


FIG. 1.—Lower part of pharynx and upper part of œsophagus, viewed from behind. *A*, cricoid cartilage. *B*, fibres of inferior constrictor decussating at median raphe. *C*, lower or 'œsophageal' part of inferior constrictor. *D*, the V-shaped interval between the lateral bands, thinly covered by irregular longitudinal fibres. *E*, the two lateral bands formed above by the longitudinal fibres. *F*, Trachea. *G*, the longitudinal fibres forming a continuous layer all round œsophagus below.

are said to divide into three longitudinal bands—an anterior, attached to the vertical ridge on the back of the cricoid cartilage, and two lateral bands which are described as becoming

connected above with the lower fibres of the inferior constrictor (Quain, etc.), or with the elastic tissue in which the palato-pharyngeus ends (Macalister)—I have never felt quite satisfied. Independent of the fact that I had never seen such an arrangement shown to my satisfaction in a dissection, it appeared to me extremely improbable that the lateral bands described, formed as they were of longitudinal fibres, should join the nearly horizontal fibres of the lower edge of the inferior con-

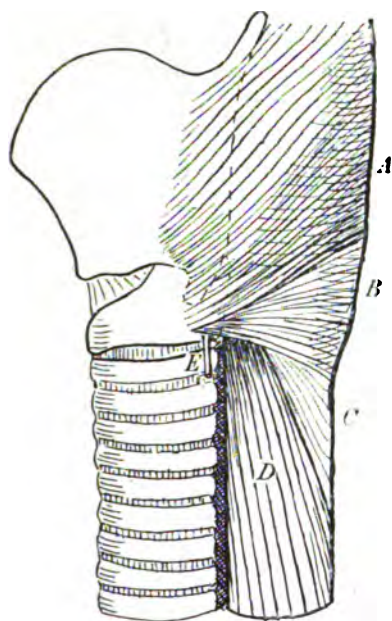


FIG. 2.—Lower part of pharynx and upper part of œsophagus, viewed from the side. *A*, upper part of inferior constrictor. *B*, lower or 'œsophageal' part of inferior constrictor. *C*, the V-shaped interval between the lateral bands *D*, which are shown winding round to the front and passing beneath the lower margin of inferior constrictor. *E*, recurrent laryngeal nerve.

strictor. Nor did it seem likely that these important bands, which had so much to do with the fixation of the œsophagus, would be dependent upon such a slight support above, as that offered by the elastic tissue connected with the lower part of the palato-pharyngeus.

Suitable material having come into my hands, I recently made a careful study of these fibres on a series of dissections which I

had specially prepared with this object, and as a result, I would offer the following account of the arrangement of the muscular fibres in the lower part of the pharynx and the upper end of the œsophagus.

The outer or longitudinal muscular fibres form over the œsophagus generally, with the exception of its upper end, a well-developed continuous layer of longitudinal bundles, running parallel to one another, and in the direction of the tube. This layer, which is considerably thicker in general than the circular layer, will be distinctly displayed if the connective tissue which lies outside the muscular coat be carefully and completely removed from an œsophagus which has been moderately distended and still retains its connections with the larynx.

On viewing the posterior aspect of such a preparation, it will be seen that the longitudinal fibres form on this surface a continuous layer until a point 1 to $1\frac{1}{2}$ inches below the cricoid is reached. Here the layer of longitudinal fibres on the back of the tube divides into lateral halves (E E, fig. 1), which gradually separate from one another and wind round to the lateral aspect, leaving a V-shaped interval between the diverging masses above (D, fig. 1). As they pass round to the sides these fibres form two stout longitudinal bands, the bundles of which run obliquely or somewhat spirally upwards and forwards (D, fig. 2). They ascend beneath the lower margin of the inferior constrictor, and having been joined by the longitudinal fibres of the side and front of the gullet, they wind round to the front, where meeting, they end below the middle of the back of the cricoid, in a stout flat tendon (A, fig. 3), through the medium of which they are attached to the cricoid cartilage. This tendon, which is about $\frac{1}{4}$ inch in width above, and somewhat wider below, runs up over the back of the cricoid, and having been joined by certain other fibres, which will be described below, it is finally attached to the upper end of the vertical ridge of the cricoid cartilage, near the point at which this ridge passes into the upper border of the quadrilateral plate (fig. 3.)

Whilst this is, so far as I can see, the usual termination of these two lateral bands of longitudinal fibres in the majority of cases, still it will be occasionally found that some few of the superficial and posterior fibres of the lateral bands are connected to

the lower margin of the inferior constrictor (evidently by the intervention of connective tissue) (B, fig. 4). In other cases a few of the superficial fibres form a small independent bundle, which is attached above to the lateral part of the inferior margin of the cricoid cartilage (A, fig. 4).

As the 'longitudinal bands' described above pass forwards and upwards round the side of the œsophagus, their disposition is

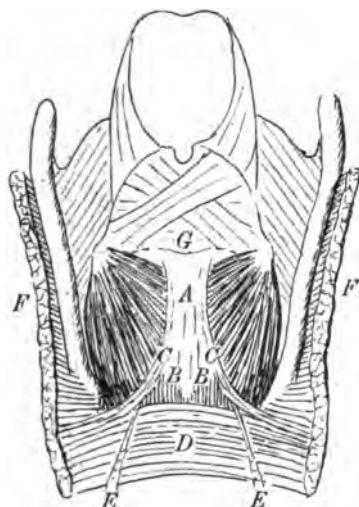


FIG. 3.—The posterior wall of the pharynx and of the upper end of the œsophagus has been cut along the middle line and turned out on each side, the mucous membrane and submucosa have been removed to show, *A*, the common tendon of the two lateral bands *B B* which have now come to the front, and are shown joining the tendon. *C C*, the highest bundles of circular fibres of œsophagus joining the lateral margins of the common tendon. *D*, circular fibres of œsophagus. *E E*, two very slight slips often found descending from margins of common tendon, and running backwards and downwards to join circular fibres. *F*, cut edge of inferior constrictor. *G*, upper border of cricoid cartilage.

such that, on casual examination, one might easily fall into the error of thinking that they were connected to the lower margin of the inferior constrictor. A careful dissection, however, will show that this is not the case, and that while none, or at most a few fibres in exceptional cases, are attached to the inferior constrictor, the bands pass on beneath the lower margin of this muscle (fig. 2) to reach their common tendon on the front, as already described.

The arrangement of the longitudinal fibres, as given above, will be better understood if, instead of tracing them from below upwards, we follow the more natural plan of tracing them from their origin above, downwards along the tube, thus:—The longitudinal fibres of the œsophagus arise by a stout tendon— $\frac{1}{4}$ in. in width above—from the upper end of the vertical ridge on the back of the cricoid. This tendon, somewhat below the middle of the cricoid, gives rise to two stout muscular bands, which lie close together on the front of the tube at their origin,

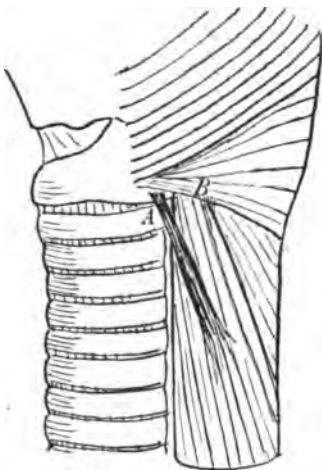


FIG. 4.—Lower part of the pharynx and upper part of the œsophagus, viewed from the side; showing *A*, an occasional muscular slip from the lateral band to the cricoid cartilage; and *B*, a few superficial posterior fibres of the lateral bands connected to the lower margin of inferior constrictor by connective tissue.

but diverge immediately below this, each passing round on the lateral aspect, and gradually spreading out in a dorsal direction, until finally, at a point about $1\frac{1}{4}$ inches below the cricoid, the fibres of opposite sides meet behind, and form, from this down, all round the tube, a continuous layer of longitudinal fibres.

This arrangement will be made clearer by a reference to the accompanying figures 1, 2, 3.

If the front of the upper portion of the œsophagus be examined, the two 'longitudinal bands' will be seen winding round from the sides, and meeting higher up, before their

common tendon is reached. Below this meeting, the comparative fewness of the longitudinal fibres on this aspect near the middle line, is noticeable for some few inches down; so few indeed are the fibres of the outer layer here, that often the circular fibres are distinctly visible through their scant covering.

If we next turn our attention to the posterior aspect of the upper end of the tube, two questions will naturally arise:—How is the V-shaped interval on the back between the diverging lateral bands filled? and, How is the muscular wall of the œsophagus connected posteriorly to that of the pharynx?

As regards the first question, it may be briefly stated that the V-shaped interval, which measures nearly $1\frac{1}{4}$ inches from above downward, is filled by the circular fibres of the œsophagus, covered over in its lower and greater portion by thin and scattered longitudinal fibres derived from the outer layer, and above for nearly half-an-inch by the lowest fibres of the inferior constrictor, which pass down for a short distance over the upper part of the œsophagus, overlapping and blending with its highest circular fibres.

If the outer surface of the inferior constrictor be carefully dissected, it will be seen that this muscle is made up of two parts differently arranged—(a) an upper and much larger portion, consisting of all the fibres springing from the thyroid cartilage, and the upper and superficial portion of those arising from the cricoid (B, fig. 1, and A, fig. 2); and (b) a lower part, consisting of the deeper fibres of the cricoid origin (C, fig. 1, and B, fig. 2). The muscular bundles in the upper division are of a redder colour, and run obliquely upwards and towards the middle line, where they join the *raphé*—or, more correctly, decussate irregularly with those of the opposite side—in the middle line. The lower division of the inferior constrictor is paler in colour, and is made up of fibres which are more horizontal in direction, and which, unlike those of the upper division, *do not decussate or form a raphé*, but, on the contrary, run continuously from side to side in the form of annular (or, more correctly, C-shaped) bundles. This, which might be described as an œsophageal portion of the inferior constrictor, is apparently transitional between the constrictor and the circular fibres of œsophagus, is

evidently specially modified in order to serve (somewhat after the fashion of the 'adapter' of a syringe) as the means of union between the muscular coats of the œsophagus and pharynx. It is narrow at each end, where it springs from the postero-lateral aspect of the cricoid below, and under cover of (i.e., internal to) the cricoid origin of the main division of the constrictor. It is much wider—nearly $\frac{3}{4}$ inch—in the middle, being somewhat diamond-shaped, with the long axis horizontal. Above, it runs up into the interval between the lowest pair of decussating bundles of the constrictor; while inferiorly it passes down for over $\frac{1}{4}$ inch, filling the upper and wider part of the V-shaped interval between the two lateral bands, here overlapping and blending with the highest circular fibres of this part of the œsophagus. Its lower margin is very distinct on the lateral aspect (fig. 2), where it is seen passing back from the cricoid across the recurrent nerve and the longitudinal band of the œsophagus. But posteriorly it is much less distinct; in fact, it is frequently difficult to define it with certainty here. In this way the upper part of the V-shaped space is filled in.

The lower portion of the V is occupied by the circular fibres of the œsophagus, covered by an extremely thin sheet of somewhat pinnately arranged fibres, derived from the outer layer (D, fig. 1). If the two 'longitudinal bands' descending from their tendon of origin round the sides of the œsophagus be carefully examined, it will be seen that while the main mass of the two bands meet only at a point about $1\frac{1}{4}$ inches below the cricoid, scattered fibres start off from their posterior margins at different levels, which wind round more rapidly to the back and meet (or decussate) in the middle line posteriorly. The highest of these fibres come off from the lateral bands near their upper ends, and pass back, forming very open V's, immediately below the 'œsophageal portion' of the inferior constrictor, while the succeeding fibres form more and more acute V's, until they finally fit into the angle between the two longitudinal bands, where these meet below. This arrangement will be made clearer on referring to fig. 1, which gives a posterior view of the upper end of the œsophagus.

Such is the arrangement of these fibres. It must, however, be understood that they form an extremely thin and scant layer,

but imperfectly hiding the circular fibres, which really fill up the V-shaped gap between the longitudinal bands.

There still remains for us the second question—How do the circular fibres end above?

By dividing the larynx and trachea, and with them the anterior wall of the œsophagus, along the middle line, and then removing the mucous membrane and submucosa from the posterior wall of the pharynx, etc. (fig. 5), it can be shown that the circular fibres at the back of the œsophagus pass into continuity with the deeper fibres of the 'œsophageal portion' of the inferior constrictor; and it is difficult, on inspecting this part (posterior wall) alone, to tell where one ends and the other begins. On passing round to the lateral and anterior aspect, however (fig. 3), the highest circular fibres of the œsophagus can be easily determined; and, as pointed out below, they will be found joining the two margins of the common tendon of the longitudinal fibres (C, fig. 3).

It will sometimes, but not invariably, I think, be found on making the above dissection that the highest and deepest circular fibres of the œsophagus on this aspect show a slight obliquity (the fibres sloping a little upwards as they approach the middle line), with a tendency to a faint decussation (E, fig. 5). On each side of the middle line the fibres, apparently after decussating, are connected with two thin flat muscular slips (D, fig. 5), which arise, one on each side, about the level of the middle of the thyroid ala, from the elastic tissue of the submucosa (the pharyngeal aponeurosis), in which the palatopharyngeus muscles (B, fig. 5) end inferiorly. With these latter muscles the two little slips referred to (which constitute a pair of pharyngo-œsophageal muscles) are at least in functional continuity, and their use is apparently to fix the circular fibres of the œsophagus posteriorly.

Two somewhat similar but much smaller slips (E, fig. 3; F, fig. 5) are occasionally found passing downwards and backwards from the margin of the common tendon of the longitudinal fibres to join the circular fibres. These two sets of slips are the only and very slight foundation which I can find for the third layer of muscular fibres described in some books in the upper part of the gullet.

If we follow the highest circular fibres from the back round to the sides, we shall find that they do not meet in front (I refer now to the very highest bundles of this layer for a distance of only about $\frac{1}{16}$ of an inch from the top of the tube). Instead of meeting in front, when they reach the antero-lateral aspect of the tube, they run up along the outer margin of the longi-

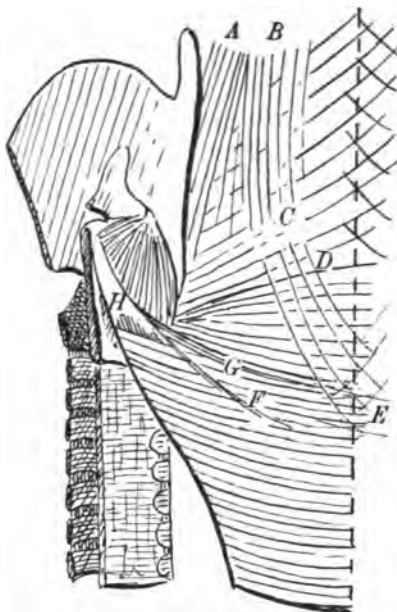


FIG. 5.—The larynx, trachea, and anterior wall of oesophagus have been divided and pulled apart, and the posterior wall of pharynx and oesophagus shown by removing mucous membrane, etc. (only one-half of specimen represented). *A* and *B*, stylo- and palato-pharyngeus, the latter ending at *C* in elastic fibres, from which arise a few slender bundles, *D*, which run downwards and inwards, decussate at middle line, and join circular fibres of oesophagus at *E*, and help to fix these fibres. *F*, few fibres coming from margin of common tendon, *H*, and going to join circular fibres of oesophagus. *G*, highest circular fibres of oesophagus. (The lower part of above is very diagrammatic, the oesophagus being much too wide.)

tudinal bands, now come to the front, and join the outer edge of their common tendon (*A*, fig. 3; *G*, fig. 5); so that not only the longitudinal, but also the circular fibres are united to the top of the vertical ridge of the cricoid. Indeed, these upper fibres just referred to seem to form a transitional stage between

the ordinary circular fibres of the œsophagus and the 'œsophageal portion' of the inferior constrictor.

The fibres immediately beneath these just described meet in front, having previously crossed on the posterior aspect of the upper end of the longitudinal bands, and thus form complete rings (see above, D, in fig. 3).

Briefly, then, it may be said that the circular fibres of the œsophagus end as follow:—Posteriorly, by becoming continuous with the corresponding fibres of the œsophageal portion of the inferior constrictor; on the lateral aspect, the highest fibres form a small bundle, which is united on each side to the margin of the common tendon of the longitudinal fibres, and thus to the cricoid; whilst anteriorly, having previously become very thin, they finally cease a little below the level of the junction of the longitudinal bands with the common tendon (see fig. 3).

A very good demonstration of the two longitudinal muscular bands, of their meeting above on the anterior aspect of the tube, and of their connection with the tendon which attaches them to the cricoid, can be obtained by dividing the œsophagus 4 or 5 inches below the cricoid, cleaning its anterior surface, and separating it from the trachea, and, higher up, from the cricoid, the latter being facilitated by cutting the lower fibres of the inferior constrictor on each side. On first making this dissection, one is rather surprised to find that the œsophagus can be easily separated from the back of the cricoid, almost as far as its superior border, displaying fully the crico-arytenoid muscles, while leaving the œsophagus intact. One is, perhaps, also surprised to find that the anterior wall of the tube is tendinous above.

A more striking demonstration still is got by slitting up the posterior wall of the lower portion of the pharynx and upper part of the œsophagus, pinning out the sides, and removing the mucous membrane and submucosa, with the greatest care, from the anterior wall. The upper termination of the circular fibres, and the ending of the longitudinal fibres on the tendinous band running up to the top of the cricoid, as in fig. 3, are shown in a very distinct and interesting way.

In most specimens it will be found that a few slips of the

longitudinal fibres are attached to the back of the trachea, and, higher up, to the connective tissue over the lower end of the ridge of the cricoid.

SUMMARY.

The longitudinal fibres of the œsophagus do not, as usually described, divide above into three bands—an anterior and two lateral. At a point on the back of the tube about $1\frac{1}{4}$ inches below the cricoid, the longitudinal fibres of each lateral half diverge from one another, forming *two* 'longitudinal bands,' with a V-shaped interval between them. The two bands gradually wind upwards and forwards round the side of the œsophagus, pass beneath the lower margin of the inferior constrictor (with which sometimes a few of the fibres are connected by connective tissue), and coming to the front, meet but do not unite, and end somewhere below the middle of the cricoid, on a stout common tendon about $\frac{1}{4}$ inch wide, which is attached above to the upper end of the vertical ridge on the back of the cricoid. (It is preferable, in describing the longitudinal fibres, to trace them from the common tendon downwards, spreading dorsalwards, and meeting $1\frac{1}{4}$ inches below the cricoid, etc.) The V-shaped interval between the diverging bands is filled by the circular fibres of the œsophagus, thinly covered below by irregular pinnately arranged or decussating fibres, derived from the longitudinal layer, and above by the overlapping lower edge of the 'œsophageal portion' of the inferior constrictor, with which the circular fibres blend.

The circular fibres end superiorly, on the posterior aspect, by blending with the fibres of the œsophageal portion of the inferior constrictor. The highest bundle on the lateral aspect is prolonged forwards and upwards on each side to the outer margin of the common tendon of the longitudinal fibres; whilst in front the circular fibres gradually thin off, and finally cease a little distance below the middle of the cricoid.

The lower or 'œsophageal portion' of the inferior constrictor differs from the rest of that muscle in that its fibres are continuous from side to side, and do not decussate, or join the

raphé. It is evidently transitional between the circular fibres of the œsophagus and the inferior constrictor proper.

At the back, on taking off the mucous membrane, etc., carefully, there are generally found running downwards and inwards, a little distance from the middle line on each side, a few thin and scattered muscular bundles, constituting a pharyngo-œsophageal muscle, which arises above from the tissue in which the palato-pharyngeus ends, and terminates below by decussating with its fellow, and joining the circular fibres near the upper end of the œsophagus, which fibres it helps to fix.

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THE ARRANGEMENT OF THE MUSCULAR FIBRES OF
THE STOMACH. By A. BIRMINGHAM, M.D., *Professor of
Anatomy, Catholic University, Dublin.*

A SHORT time ago, when making a careful dissection of a stomach, in which the muscular fibres were particularly well developed, I was surprised to find that the arrangement of these fibres differed in several important details from the descriptions found in all our text-books, I believe, without exception. My attention having been directed to the matter, I examined a number of stomachs; and as each corroborated the evidence of the first, I have come to the conclusion that our current descriptions of the muscular coat of this organ are at variance with the facts which can be brought out by a careful dissection in any ordinary stomach the muscular coat of which is fairly well developed, particularly if it has not been artificially thinned-out by post-mortem over-distension, for the purpose of facilitating dissection, or otherwise.

As an example of the text-book descriptions, I shall give a summary of the account of the muscular coat found in the tenth edition of *Quain's Anatomy*, with which account, I may add, our other text-books practically agree.

Quain's description is as follows:—The muscular coat consists of three sets of fibres disposed in layers, and named from their direction the longitudinal, the circular, and the oblique fibres.

The longitudinal fibres are continuous with those of the œsophagus; they spread in a radiating manner from the cardiac orifice, and are found in greatest abundance along the curvatures, especially the lesser one. On the anterior and posterior surfaces they are thinly scattered or scarcely to be found, but are well marked, and form a thick uniform layer near the pylorus.

The circular fibres form a complete layer over the whole extent of the stomach. "They commence by small and thinly scattered rings at the extremity of the great cul-de-sac, describe larger and larger circles as they surround the body of the

stomach at right angles to its curved axis, and towards the pyloric end again form smaller rings, and at the same time become much thicker and stronger than at any other point. At the pylorus itself they are gathered into a thick bundle, which forms, within a circular fold of mucous membrane—the pyloric sphincter. Some of the circular fibres appear to be continued from those of the œsophagus, spreading from its right side.”

“The innermost muscular layer is incomplete, and consists of the oblique fibres. These are continuous with the circular fibres of the gullet, on the left of the cardiac orifice, where they form a considerable stratum; from that place they descend obliquely on the anterior and posterior surfaces of the stomach, where

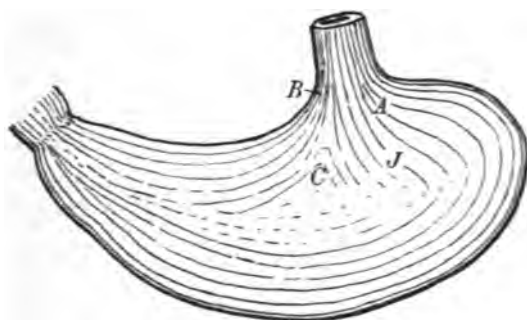


FIG. 1.—Outer layer of muscular coat of stomach. The longitudinal fibres of the front of the œsophagus are seen passing at *A* towards the fundus, and on to the great curvature, at *B* on to the lesser curvature, and at *J* blending with the underlying fibres of the middle layer. The fibres of this outer layer form a continuous covering all over the greater part of the stomach, but in the region marked *C* they are irregularly disposed or wanting.

they spread out from one another, and, taking the direction of the circular fibres, gradually disappear on the greater curvature.”

Taking as the basis of my description the usual division of the muscular coat into three layers—an outer, a middle, and an internal—I have invariably found in stomachs suitable for a proper dissection of this coat the following arrangement, which is, I would submit, the true disposition of these layers.

The Outer, or Layer of Longitudinal Fibres.—As regards these fibres I have little to say that does not agree with the usual accounts in our text-books. Its fibres are, of course, continuous with the longitudinal fibres of the œsophagus, and they form on

each curvature, but particularly on the lesser, a well-marked layer of numerous distinct bundles, which thin off as the two surfaces are reached. The layer exists, nevertheless, all over the greater part of these surfaces as a very thin sheet, the fibres being less distinctly longitudinal in places—particularly near the middle of the surfaces beneath the cardia—than in the neighbourhood of the curvature (C, fig. 1). The fibres from the right side of the œsophagus pass along the lesser curvature; while those from the left side can be traced over the summit of the fundus, and along the great curvature to the pylorus, some distance from which the fibres of the two curvatures, spreading out, meet and form a continuous and well-developed layer, of nearly equal thickness all round the narrow end of the stomach. The fibres on the front and the back of the œsophagus pass to the corresponding surfaces of the stomach, some arching towards the right, and others, which are much more numerous, towards the left. These latter, as they run downward and to the left, become mixed—to a greater extent than would appear on viewing the surface of the outer layer—with the underlying fibres of the next layer, which at this part of the stomach are passing in an almost similar direction (J, fig. 1; N, fig. 2). Between these œsophageal fibres sweeping to right and left, there is an area on each surface some distance below the cardia in which the fibres of this layer are irregular or wanting.

Fig. 1 gives a good idea of the general arrangement of the layer, but it should be pointed out that many of the fibres at J in fig. 1, which appear to be continuous with the longitudinal fibres of the œsophagus, really belong to the middle layer, as can be shown by pulling off the longitudinal fibres descending from the œsophagus.

The Middle Layer.—The fibres of this layer are said—as shown in the quotation given above—to commence in the form of circles at the fundus, and to extend as a series of rings surrounding the stomach in its whole length as far as the pylorus, where they are thickened to form the pyloric sphincter. With this description I cannot agree. An obvious objection to such a description of the layer—apart from the fact that such an arrangement cannot be shown by dissection—is the difficulty, or impossibility, of tracing the continuity between fibres so disposed

and the circular fibres of the œsophagus,—a difficulty which is got over in some descriptions by avoiding the question altogether, and simply stating that the fibres of the internal or oblique layer are continuous with the circular fibres of the œsophagus, while the circular fibres are allowed to commence on their own account at the fundus, no connection of any kind with the œsophagus being mentioned.

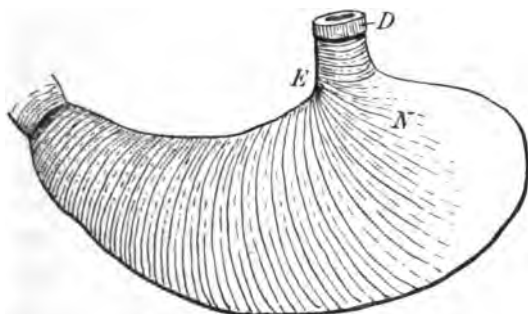


FIG. 2.—Middle layer of muscular coat of stomach. *D*, some of the outer longitudinal fibres of the œsophagus which are removed lower down, showing the superficial set of the circular fibres; these pass at *E* into the fibres of the middle layer of stomach. *N*, the oblique fibres of the middle layer, which blend to some extent with the overlying fibres of the outer layer (see *J*, fig. 1).

The current description, as quoted above, is practically correct in so far as it relates to the portion of the layer which lies to the right of the œsophagus. That part of it, however, which refers to the portion of the layer on the left of the œsophagus is entirely inaccurate, for the very simple reasons that practically no fibres of the layer, at least no annular fibres, are found to the left of the cardia, and the fibres which form rings around the wide end of the stomach, commencing at the fundus, really belong to the internal or oblique, not to the circular layer of the muscular coat.

The arrangement of the fibres of this coat will be most easily understood if we take up their description at the pyloric end, and follow them towards the opposite extremity of the stomach.

At the pylorus, as usually described, the circular fibres are numerous and well developed, constituting the pyloric sphincter, which surrounds this aperture in the form of a distinct and stout muscular ring. In the adjacent narrow portion of the stomach

the fibres are also well developed, and the resulting rings are numerous and closely placed. As we pass on towards the left the layer becomes thinner and the rings correspondingly fewer, but they still form a distinct and well-defined continuous sheet, the fibres of which can be easily seen, even through the peritoneum, forming very symmetrical rings, disposed at right angles to the long axis of the organ. This regular arrangement is continued as far as the region of the œsophagus, where it is interrupted. Here the upper portion of the rings, as they cross the lesser curvature of the stomach, 'hitch' against the termination of the œsophagus, and are prevented, as it were, from passing any farther to the left, whilst the lower portions of these fibres—namely, those on the surfaces—radiate from the right side of the cardia (where they are more or less heaped up against the œsophagus) downwards and to the left, with varying degrees of obliquity, across the surfaces of the stomach. They finally end on these surfaces a little to the left of the line of the œsophagus, where they blend with the overlying longitudinal fibres passing downwards and to the left from the front of the œsophagus, and, in part at least, turn down towards the great curvature and join the underlying circular fibres of the internal layer—a termination similar to that of the oblique fibres of the internal layer (fig. 2). These fibres of the middle layer, which I have just described as radiating from the right side of the œsophageal orifice, pass by a gradual transition on the right side into the ordinary circular rings of the stomach, without any sudden change in their direction (fig. 2); whilst tracing them onwards towards the left they will be found to become gradually more oblique, passing from the right edge of the cardia to higher and higher positions on the two surfaces, until, finally becoming horizontal (E, fig. 2), they pass into the most superficial of the circular fibres of the œsophagus.

This arrangement can be reproduced diagrammatically by taking a distended stomach with a portion of the œsophagus attached, and passing on to it, over its pyloric end, a large number of elastic rings to represent the circular fibres. In the neighbourhood of the pylorus and the adjacent parts of the stomach the rings should be disposed in a continuous series at right

angles to the long axis of the stomach, until the œsophagus is reached. The next ring after this having been passed over the pyloric end, should be drawn across the stomach until its upper end is caught by the œsophagus, its lower end should be then moved a little way towards the fundus; the succeeding ring having been carried as far as the œsophagus above, should have its lower end drawn still further to the left, and so on, until finally a ring is put on which, when its upper end hitches against the œsophagus, has its lower end carried to the left, right over the fundus, so that it will come to lie as a band around the termination of the œsophagus (fig. 2).

It should be added that, unlike the elastic bands in the arrangement just described, the fibres which radiate from the right side of the œsophagus downwards and to the left across the two surfaces of the stomach do not form complete rings, but that, having blent to some extent with the overlying prolongations of the longitudinal fibres of the œsophagus on the front and back of the stomach (which are running in the same direction), and to a slight extent with the circular fibres of the internal layer, they become lost on the surfaces, and cannot be followed to the region of the great curvature.

The Internal Layer.—As I traced the circular fibres from the pylorus, I may, for convenience, trace these fibres from the fundus, for they are arranged on the portion of the stomach which lies to the left of the œsophagus, in practically the same manner as the circular fibres are arranged on the portion of the stomach to the right of the œsophagus. They begin as circles at the summit of the fundus (L, fig. 3), whence, forming larger and larger circles, they pass to the right in the form of rings encircling the wide end of the stomach, and disposed at right angles to the long axis of this part of the organ. When they reach the left side of the œsophagus the upper ends of the rings ‘hitch’ against it (an arrangement similar to that described on the opposite side of this tube in connection with the middle layer), whilst the rest of the rings radiate with increasing degrees of obliquity from the left side of the cardia across the two surfaces, as the well-known and commonly-described ‘oblique fibres’ of the stomach (fig. 3). Of these oblique fibres those nearest to the fundus run with a very slight degree of obliquity,

for the transition from the fibres which form rings round the wide end of the stomach to the well-known oblique fibres is very gradual. The next fibres are more distinctly oblique, and are carried a considerable distance towards the pyloric end, whilst the succeeding and highest fibres run nearly parallel to, and no great distance from, the lesser curvature, reaching almost as far as the antrum pylori. Above this (K, fig. 3) the oblique

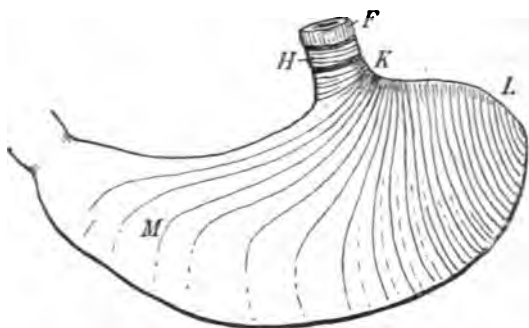


FIG. 3.—Internal layer of muscular coat of stomach. *F*, longitudinal fibres of œsophagus, removed at *H* to show the superficial set of circular fibres. *K*, deep circular fibres of the œsophagus passing below into continuity with fibres of internal layer of stomach. *L*, fibres of internal layer forming rings round fundus. *M*, oblique fibres of internal layer, ending by turning abruptly towards great curvature, and passing into circular fibres of the overlying middle layer.

fibres are continuous with the deeper circular fibres of the œsophagus.

It should be pointed out here that the circular fibres at the termination of the œsophagus are divisible into a superficial set continuous with the fibres of the middle layer of the stomach, which radiate from the right side of the cardia, and a deep layer, which are similarly continuous with the oblique fibres of the internal layer. Not that these two sets of the circular fibres are distinctly separated from one another in the œsophagus, but it will be found, on removing the longitudinal fibres at the lower end of the tube, that the circular fibres lying immediately beneath assume, as the stomach is approached, an oblique direction, as if the left end of the rings which these fibres form were slipping down at that side of the tube on to the stomach; below this they are seen to be continuous with the fibres of the

middle layer of the muscular coat (E, fig. 2). If these superficial circular fibres just described be removed, it will be found that there lies beneath them another set, the deeper circular fibres, which becoming oblique in the opposite direction, slip down along the right margin of the œsophagus as the stomach is approached, and pass into the oblique fibres of the internal layer of the stomach (K, fig. 3).

It will be remarked that in both the middle and internal layers circular and oblique fibres are found. The *circular* fibres surround all of the stomach to the right of the œsophagus in the middle layer, all to the left of the œsophagus in the internal layer, the *oblique* fibres of the middle layer radiate from the right margin of the cardia downwards and to the left, whilst in the internal layer they radiate from the left margin of the cardia downwards and to the right, in each case on both surfaces of the stomach.

The termination of the oblique fibres of the internal layer, I found, corresponded to the description given in our text-books. They all, so far as I could make out, after passing across the surfaces of the stomach obliquely for variable distances, turn rather abruptly towards the great curvature and join the circular fibres of the middle layer (M, fig. 3). As pointed out above, at least some of the oblique fibres of the middle layer terminate in a corresponding fashion.

SUMMARY.

The muscular coat of the stomach consists of three incomplete layers—External, Middle, and Internal.

1. *The External Layer* consists, as usually described, of longitudinal fibres continuous with those of the œsophagus, best marked on the lesser curvature when the stomach is distended, also well seen on the great curvature and near the pylorus, but represented in practically all other parts by a thin layer, the fibres of which are irregular on the two surfaces below the cardia.

2. *The Middle Layer* is composed of circular and oblique fibres: the former, which are the more numerous, are found in the form of rings surrounding the stomach from the sphincter pylori,

which they form, to the cardia. Beyond this the layer is continued for some distance in the form of oblique fibres, which radiate from the right side of the œsophageal opening above, downward and to the left on the two surfaces of the stomach. These fibres, becoming more and more oblique, are continued above into the superficial circular fibres of the lower end of the œsophagus. The fibres of this layer do not, as usually described, encircle the wide end of the stomach with a series of rings; these rings belong to the next layer.

3. *The Internal Layer* is composed, like the middle layer, of circular and oblique fibres; but whilst the oblique fibres are but slightly developed in the middle layer, they form an important part of the internal layer. Beginning as a series of circles at the summit of the fundus, it extends in the form of a layer of rings, disposed at right angles to the axis of the stomach, as far as the cardia. Beyond this it is continued by a number of fibres—the well-known oblique muscular fibres of the stomach—which radiate from the left side of the œsophageal opening, downwards and to the right on both surfaces of the stomach, some of them reaching almost as far as the antrum pylori. These fibres end by turning abruptly towards the great curvature and passing into the circular fibres of the middle layer. The highest of these oblique fibres pass above into the deeper circular fibres of the œsophagus.

THE MARSUPIAL LARYNX.¹ By JOHNSON SYMINGTON,
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THE larynx of the Marsupialia is well known to differ in several important respects from that of the higher mammals, while, so far as it has been examined, it has not presented any very important variations in its structure amongst the different members of this group of mammals. Several interesting papers on its anatomy have been published: but various peculiarities in its structure have been imperfectly or incompletely described, and their morphological and functional significance overlooked or misunderstood. This is largely due to the fact that our information as to the structure of this organ rests mainly upon the naked-eye examination of adult specimens. The following communication is an attempt, so far as the material at my disposal permits, to make our knowledge of the larynx in various marsupials more complete and accurate.

The majority of my specimens belonged to the Macropodidæ, but I have also examined pouch and adult specimens of Phalangistidæ and Didelphyidæ and a representative of the Phascolomyidæ (an adult wombat). The following description is based mainly upon the study of adult and pouch specimens of Macropus, chiefly *M. bennettii*. Where the other families examined presented any distinct deviation from that of the Macropodidæ, attention will be directed to their peculiarities.

RELATION OF THE LARYNX TO NEIGHBOURING STRUCTURES.—In 1881 Rückert (1) published an important memoir, in which he showed that the position of the larynx in relation to the base of the skull, the vertebral column, and the soft palate, was quite different in ordinary mammals from that which obtains in man. In the former it lies higher up and further forward under the base of the skull, and the epiglottis projects behind the soft palate, into the nasal part of the pharynx. I (2) have shown

¹Part of this paper was read and specimens exhibited at a meeting of the Section of Anatomy and Physiology of the Royal Academy of Medicine in Ireland, Jan. 1898.

that in the young human foetus the larynx occupies a position in relation to the vertebral column somewhat corresponding to that of ordinary mammals, but that it gradually descends during the later portion of foetal life, and during infancy and childhood, gaining its adult position about puberty. At no period of life, however, in the human subject, is the epiglottis found in the naso-pharynx.

During recent years considerable attention has been directed to the so-called intra-narial position of the epiglottis, more especially by Waldeyer (3), Howes (4), and Gegenbaur (5), and its existence demonstrated in the great majority of mammals. Such a position of the epiglottis must necessarily cause the food during the act of deglutition to pass from the mouth into the pharynx at the sides of the epiglottis, and the danger of food passing into the larynx is thus partially avoided. This, however, does not guard the whole circumference of the laryngeal orifice, and we find in many mammals an additional protection in the form of well-developed palato-pharyngeal folds, which meet on the dorsal wall of the pharynx. The upper end of the larynx, including the epiglottis and aditus laryngis, is thus embraced by a ring (annulus palato-pharyngeus), and projects above this ring freely into the naso-pharynx.

As a marsupial is placed after its birth in the pouch of its mother, and becomes attached, in the immature condition in which it is born, to a mammary nipple, to which it remains adherent for a considerable time, and is nourished by milk pressed out of the gland by muscular action, a special provision appears to be necessary to enable the animal to breathe without the risk of the fluid getting into its air-passages. Such a provision exists, for we find in pouch specimens not only a well-marked intra-narial epiglottis, but also a distinct arcus palato-pharyngeus, which reaches on the dorsal wall of the pharynx considerably below the entrance to the larynx. Many years ago Morgan (6) described this ring in *Hydrochoerus capybara*, as forming a well-developed sphincter muscle (palato-pharyngeus), which embraced the upper part of the larynx; and Rückert (1) figures a somewhat similar condition in the dolphin. In marsupials, however, the arcus palato-pharyngeus consists mainly of a fold of mucous membrane, between the two layers of which

there is only a thin sheet of muscular fibres. Gegenbaur (5) draws attention to this fact. In *Halmaturus Billardieri* he describes the greater part of the velum as apparently membranous, and the pharyngeal arches as very thin. The palato-pharyngeus muscle presents very considerable modifications in different mammals (see Rückert (1)), but its arrangement in the marsupials does not appear to have been carefully described hitherto.

In a series of sections of a pouch specimen of *Macropus bennettii* (head length 2 cm.) made at right angles to the long axis of the pharynx, the fibres of the palato-pharyngeus were seen to be attached to the median raphé in the dorsal wall of the pharynx. Traced from this raphé, the fibres passed outwards on either side towards the lateral wall of the pharynx, lying in close relation with and on the ventral aspect of the pharyngeal constrictor. A few of the highest fibres passed into the sides of the lower part of the soft palate, but could not be traced to the mesial plane. The upper part of the soft palate possessed well-developed tensor and levator muscles, but the portion near the lower free border was nearly destitute of muscular fibres. Below the soft palate the fibres entered the palato-pharyngeal folds, running nearly in the plane of the sections. In any given section only two or three muscular fibres were seen, and these could not be traced as far as the free edge. I also observed the absence of any muscular tissue near the free borders of the palato-pharyngeal folds in an adult *Macropus bennettii*.

From these observations it is evident that the arcus palato-pharyngeus does not contain muscular fibres arranged so as to form a distinct sphincter capable of grasping the upper part of the larynx, but that the naso-pharynx is closed against the entrance of food during the act of deglutition by mechanical means, the wall of the arcus being pressed by the food against the wall of the larynx.

CARTILAGES OF THE LARYNX.—The cartilages of the larynx consist of an epiglottis, a crico-thyroid, two arytenoids, and an interarytenoid.

With regard to the epiglottis, I have nothing new to add to the observations of Gegenbaur (5).

Crico-thyroid.—One of the most striking and obvious peculiarities of the marsupial larynx is the union anteriorly of the cricoid and thyroid cartilages. In a median section of the larynx the cricoid and thyroid appear as a continuous line of cartilage, and even on microscopic examination no peculiarity in histological structure indicates the line of union. This union corresponds to about the anterior fifth of the circumference of the larynx. The thyroid is also closely connected with the sides of the cricoid by means of its posterior cornua. These processes extend backwards external to the lateral parts of the cricoid,

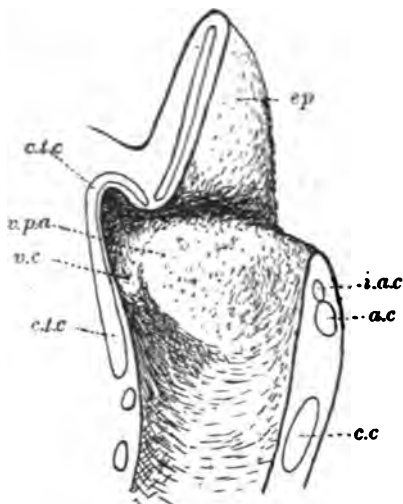


FIG. 1.—Median section of larynx of *Macropus bennettii* (adult). *ep.*, dorsal surface of epiglottis; *c.t.c.*, crico-thyroid cartilage; *c.c.*, cricoid cartilage; *a.c.*, internal process of arytenoid cartilage; *i.a.c.*, interarytenoid cartilage; *v.p.a.*, vocal process of arytenoid cartilage; *v.c.*, vocal cord.

and are firmly united with them, sometimes by a short ligament, more usually by an actual fusion of the two cartilages.

Gegenbaur found a complete blending of the cricoid and thyroid anteriorly in a 3 cm. long pouch specimen of *Perameles*, and I have observed the same thing in several somewhat larger pouch specimens of *Macropus*. In a younger *Macropus*, however, measuring 2.1 cm. from the front of the head to the root of the tail, and with a head length of .75 cm., the cartilages of the cricoid and thyroid had not blended anteriorly, the two being

separated by rather dense embryonic connective tissue. Unfortunately, this is the only specimen I possess at this stage of development, but it may be regarded as an indication that the union of the cricoid and the thyroid in marsupials is a secondary process. In this specimen the two alæ of the thyroid were well developed, and about midway between their upper and lower borders came close together; but even here there was a narrow gap, composed of closely packed cells, separating the two alæ. The space between the two alæ became broader above and below this point.

Kallius (7) has recently investigated the development of the thyroid cartilage in the human subject, and found that in an embryo 40 to 42 days old the two lateral plates of the thyroid were separated anteriorly by a broad band of embryonic connective tissue. It may be fairly assumed that the cricoid and thyroid are developed in essentially the same way in the Marsupialia as in the higher Mammalia. With regard to the fusion of the thyroid and cricoid, Gegenbaur points out that this process makes the larynx a more effective organ of support to the epiglottis. This is no doubt true, but it does not explain the cause of the fusion. As we shall afterwards see, the vocal cords become extremely rudimentary in the Marsupialia, and a large number of these animals are voiceless. Under these circumstances, the movements between the cricoid and thyroid which are associated with the tightening and relaxation of the vocal cords are not called into play; and we know that when adjacent skeletal elements are not made to move one upon the other, there is a marked tendency to their more or less complete fusion.

In almost all cases the upper and median portion of the thyroid cartilage is dilated to form a recess the cavity of which is lined by mucous membrane continuous below and behind (dorsally) with that of the larynx, while the convex upper and ventral aspect is directed towards the hyoid. Albrecht (8) describes this bladder-like dilatation as being very highly developed in *Cuscus*, where it projects into the base of the tongue, while he found it entirely absent in *Phascogalea cinereus*. Gegenbaur (4) figures it in *Phalangista vulpina* as forming a large flask-shaped recess opening below into the larynx. In the Virginian opossum (see fig. 5) the median portion of the united

cricoid and thyroid cartilages are curved, with the concavity directed towards the interior of the larynx; this curve involves the whole length of the cartilage, and its upper end does not present the hook-like form seen in the majority of marsupials.

This recess is formed at an early period. Thus in a young phalanger, which measured from the front of the head to the root of the tail 20 mm., several horizontal sections through the upper part of the thyroid showed a marked thickening of the anterior part of the cartilage, and embedded in this a central cavity lined by mucous membrane. An examination of the series of sections showed that this cavity opened below into that of the larynx, and ended blindly above.

The thyroid exhibits a decided tendency to ossify, the process beginning at an early period. In a pouch specimen of a kangaroo, head length 2 cm., ossification had commenced in each ala, near its inferior cornu. In an adult *Macropus bennettii* the ossified area was situated towards the posterior part of the ala, and in no marsupial have I observed any ossification of the portion of the thyroid uniting its two lateral plates.

Gegenbaur, in a view of the larynx of an adult *Phalangista vulpina* from behind, figures the cricoid cartilage as being incomplete posteriorly (see fig. x. B), but he makes no reference to this in his text. The point, however, is of some interest in connection with the generally accepted view that the cricoid is simply a modified tracheal ring. In all the specimens of marsupial larynges that I have examined, the cricoid formed a complete ring as in the higher Mammalia.

Arytenoids.—The arytenoids appear to be highly developed in all the marsupials. They articulate with the posterior part of the upper lateral borders of the cricoid, and reach upwards close to the aditus, forming the lateral boundaries of this opening in the greater part of its extent. Each arytenoid possesses three well-developed processes—an anterior or vocal, an external or muscular, and an internal or articular. The two first mentioned do not differ essentially from those of other mammals, but the internal process is well developed, and articulates with the corresponding process of the opposite side (see fig. 2). This peculiarity of the arytenoid appears to have been almost entirely overlooked. Albrecht (8) merely states

that in *Didelphys lanigera* the two arytenoid cartilages have grown together posteriorly. Körner (9), in a description of the cartilages of the larynx of an adult specimen of *Halmaturus giganteus*, mentions these processes, and describes them as nearly meeting in the middle line; but according to his account and figures they are covered on their dorsal aspect by a butterfly-like cartilage—the interarytenoid. I have found this interarytenoid



FIG. 2.—Horizontal section of larynx of pouch specimen of *Macropus bennettii*—head length 2 cm. *th.c.*, thyroid cartilage; *a.c.*, arytenoid cartilage; *v.c.*, vocal cord; *th.a.m.*, thyro-arytenoideus muscle; *ph.*, cavity of pharynx; *a.p.ph.*, arcus palato-pharyngeus; *i.c.m.*, inferior constrictor muscle of the pharynx.

articulation in every marsupial larynx that I have examined. It appears to form a fulcrum round which the arytenoid cartilages rotate, so as to separate and approximate the vocal processes. When the larynx is exposed from behind by the reflection of the dorsal wall of the pharynx, the position of this joint can generally be recognised by a mesial swelling on the dorsal wall of the larynx a little below the aditus laryngis, and I have not seen an interarytenoid or any other cartilage lying between this joint and the pharynx, as figured by Körner.

The arytenoid cartilage possesses a considerable ventro-dorsal extent. Its internal and muscular processes are situated near

the base of the cartilage, but the vocal process is continuous with a ridge extending upwards nearly to the upper end of the cartilage. Above the level of the muscular and internal processes the arytenoid cartilage forms a plate flattened from within outwards. The upper part of this plate forms one of the lateral boundaries of the entrance to the larynx, and its anterior or ventral border turns inwards to form a prominence on the side wall of the larynx. This prominence increases from above downwards, and terminates below in the vocal process proper. In certain cases the upper border of the arytenoid is nearly horizontal (ventro-dorsal) in direction, and reaches nearly to the base of the epiglottis, so that the greater part of the aditus appears as a median cleft between the two arytenoids. This arrangement is well seen in the kangaroos (*M. robustus* and *M. bennettii*, also in the wombat). In some other forms, as *Didelphys virginiana*, the distinction between the upper and anterior borders of the arytenoid cartilage is not well defined, the two forming a curve, with its convexity directed upwards and forwards. In these cases the posterior part of the aditus forms a median cleft directed from behind downwards and forwards, and its anterior (ventral) limit is not well defined.

Interarytenoid.—This cartilage appears to be present in a large number of mammals, but usually in a very rudimentary form. Luschka (10) gives a drawing (see Taf. v. fig. 12) from a human larynx, but he admits that it is very rarely seen in man. In the Marsupialia it seems to be regularly present, at least I have never failed to find it. It is situated in the dorsal wall of the larynx between the two arytenoids, and it articulates with the upper surfaces of the internal processes of both these cartilages. As already mentioned, Körner figures it in *Halmaturus giganteus* as situated on the dorsal aspect of these processes, but I have never found it in that position. Dubois (11) terms this cartilage the 'procricoid.' In the Ornithorhynchus he shows (see p. 82, fig. 6) two of these cartilages—an anterior and a posterior. The anterior (cephalad) cartilage evidently corresponds to the marsupial interarytenoid; the posterior (caudad) may represent the extremities of the internal processes of the arytenoids separated from their respective cartilages and fused together. The name 'interarytenoid' appears to me to be much

more appropriate for this cartilage than 'procricoid,' as in the marsupials it is not connected with the cricoid, being separated from it by the internal processes of the arytenoids, while it is partially embedded in the arytenoid muscle.

The interarytenoid, like the epiglottis, is composed of yellow elastic cartilage. In an adult *Didelphys virginiana* sections of



FIG. 3.—Horizontal section of the larynx of a pouch specimen of *Macropus bennettii*—head length 2 cm. *th.c.*, thyroid cartilage; *v.c.*, upper part of vocal cord; *a.c.*, upper part of arytenoid cartilage; *a.m.*, arytenoid muscle; *i.a.c.*, interarytenoid cartilage.

which were stained with orcein, the elastic fibres formed a very dense network round the cartilage cells. The upper and posterior part of the arytenoids may also contain some elastic cartilage, but the great mass of these cartilages and the whole of the crico-thyroid are composed of hyaline cartilage.

CAVITY OF LARYNX AND THE VOCAL CORDS.

From the description already given of the cartilages of the larynx, it will be readily understood that the boundaries of the laryngeal cavity present certain characteristic features. There are, however, other factors to be considered as having an important influence upon the form of this cavity, more particularly the

relation of the epiglottis to the pharyngeal orifice of the larynx, the rudimentary form of the true vocal cord, and the absence of superior or false cords.

In the majority of marsupials there are no ary-epiglottidean folds bounding the laryngeal opening: the lateral borders of the epiglottis turn backwards, and gradually disappear on the pharyngeal wall, forming what are termed *plicæ laterales*. These folds are separated from the arytenoid cartilages by distinct sulci. This feature of the laryngeal orifice is due to the large size of the arytenoids, which project upwards, so that they form the lateral boundaries of the opening, and give rise to the grooves found between them and the *plicæ laterales* of the epiglottis. In some of the smaller marsupials, where the arytenoids are not so prominent, the lateral folds of the epiglottis may join the posterior part of the upper borders of the arytenoids, to form ary-epiglottic folds. The anterior boundary of the laryngeal opening is formed by the broad base of the epiglottis, where it rests upon the thyroid cartilage; the opening is therefore T-shaped—very similar, in fact, to the form which, according to Anderson Stuart (12), the closed aditus has in the human subject.

H. Albrecht (8) believes that the marsupials possess false or superior vocal cords. He regards the very slight folds found passing downwards from the base of the epiglottis to the mucous membrane covering the vocal processes of the arytenoid as representing the false cords. This view of their homology is, in my opinion, a very doubtful one. They appear to be caused by the vesicular dilatation of the upper part of the thyroid cartilage, and correspond to the lateral parts of its free dorsal border. In those marsupials in which this expanded condition of the thyroid is absent or rudimentary, the folds do not exist. Albrecht also recognises a shallow sulcus lying in front of this fold, above the true vocal cord, and continuous anteriorly with the cavity in the dilated thyroid, as representing a ventricle of Morgagni. This theory can only be accepted when the existence of a false vocal cord is proved. A large portion of the ventricular cavity is situated between the two arytenoids, the inner surfaces of which are concave, and covered by a thin mucous membrane, provided with ciliated columnar epithelium. The ventral edges of these cartilages are curved inwards, and the mucous membrane here

is thickened, and sometimes forms distinct folds. Anterior to these folds is a space having only a slight dorso-ventral extent, and in the lateral walls of which are the feebly-marked folds representing the true vocal cords. There is considerable variation amongst different marsupials as to the relative dorso-ventral extent of the respiratory and vocal portion of the glottis, but as a rule the former is about three times greater than the latter.

The true Vocal Cords.—Very little attention has been paid to

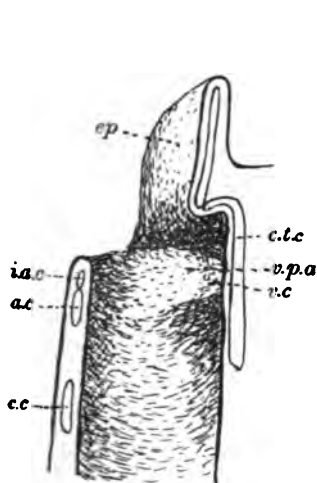


FIG. 4.

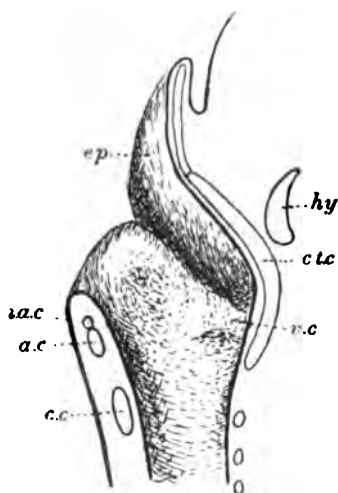


FIG. 5.

FIG. 4.—Median section of larynx of Wombat. *ep.*, dorsal surface of epiglottis; *c.t.c.*, crico-thyroid cartilage; *c.c.*, cricoid cartilage; *a.c.*, internal process of arytenoid cartilage; *i.a.c.*, interarytenoid cartilage; *v.p.a.*, vocal process of arytenoid cartilage.

FIG. 5.—Median section of larynx of *Didelphys virginiana*. *ep.*, dorsal surface of epiglottis; *hy.*, hyoid bone; *c.t.c.*, crico-thyroid cartilage; *a.c.*, internal process of arytenoid cartilage; *i.a.c.*, interarytenoid cartilage; *v.c.*, vocal cord.

these structures in the marsupials, although their condition is one of considerable morphological and physiological interest. Körner (9) in his description of the larynx of an adult *Halmaturus giganteus* wrote: "Die Stimmritze wird ausschliesslich von der Spalte zwischen den Rändern der Giessbeckenknorpel gebildet. . . . Weder ein Stimmband noch irgend eine Schleimhautfalte, die sich als solches deuten liesse, ist vorhanden" (p. 157); but in a subsequent description of the larynx of *H.*

Billardieri he recognises in this animal a rudimentary vocal cord. There is no doubt but that the vocal cord is small and not readily distinguished in some of the marsupials; still its position can always be recognised by a slight prominence on the inner wall of the larynx in front of the arytenoid cartilage, and a microscopic examination shows that it possesses a characteristic structure. When examined microscopically, the position



FIG. 6.—Coronal section of larynx of pouch specimen of *Macropus bennettii*—head length 1·8 cm. *ep.*, epiglottis; *a.p.ph.*, arcus palato-pharyngeus; *s.p.*, sinus pyriformis; *hy.*, great corner of hyoid; *v.c.*, vocal cord; on left side apex of vocal process of arytenoid is seen; *th.a.*, thyro-arytenoid muscle; *th.c.*, thyroid cartilage; *c.c.*, cricoid cartilage; X, pharyngeal orifice of larynx; *n.p.*, cavity of nasal part of pharynx.

of the vocal cord can be distinguished from the ordinary mucous membrane of the larynx by the presence of numerous layers of stratified squamous epithelium and of a well-developed layer of compact connective tissue, while glands are almost entirely absent. The connective tissue consists mainly of ordinary white fibres, staining very readily with carmine. When treated with orcein, a number of elastic fibres can be seen. These fibres have no definite direction, but ramify in an irregular manner between the bundles of white fibres. Immediately under the epithelium, however, the elastic fibres form a thin stratum composed of fine

fibres. In two pouch specimens of *Macropus bennettii*, both of about the same size, viz., head lengths 2 cm. and 1.8 cm. respectively, the vocal cords were well developed, and possessed the same structure as in the adult, except that the sub-epithelial connective tissue was in an embryonic condition, i.e., it contained a large number of cells of various forms, while the intercellular substance was not distinctly fibrillated.

The most interesting feature of the vocal cords in these two

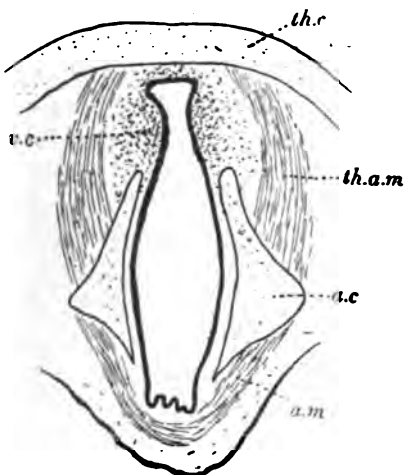


FIG. 7.—Horizontal section of the larynx of an adult *Macropus robustus*. *th.c.*, thyroid cartilage; *a.c.*, arytenoid cartilage; *th.a.m.*, thyro-arytenoideus muscle; *a.m.*, arytenoideus muscle; *v.c.*, vocal cord.

specimens was their large size (see figs. 2 and 6). In the horizontal section the vocal part of the glottis is practically twice as long as the respiratory, and in the vertical sections it will be seen to reach from a little above the level of the upper border of the cricoid cartilage upwards to the aditus laryngis. In the adult both its dorso-ventral and its vertical extent are relatively much smaller. I have not been able to investigate properly the relative development during pouch and adult life of the vocal cords in other marsupials, but it is evident that in *Macropus* the adult vocal cord must be regarded as a degenerated structure. This is interesting in connection with the well-known fact that these animals are voiceless, and it suggests the theory that they are descended from a stock which possessed a voice.

I have examined microscopically the vocal cords in adult specimens of *Macropus robustus*, *Macropus bennettii*, and *Didelphys virginiana*, and in all of them the cords had essentially the same structure. It should be noted that the vocal cord cannot be distinguished from the mucous membrane, and that, in fact, the cord may be regarded as a modification and thickening of this structure. Under the stratified epithelium the connective tissue forms a compact mass, which gradually becomes less dense as it passes outwards towards the thyro-arytenoideus muscle. In front, this muscle lies just external to the cord, but farther backwards, towards the arytenoid cartilage, these two structures are separated by loose connective tissue, and there are no muscular fibres inserted into the cord itself. H. Albrecht (8) describes the vocal cords of *Halmaturus giganteus* as covered in certain positions by ciliated epithelium, and containing glands. It must be remembered that the region corresponding to the vocal cords is not sharply defined from the adjacent mucous membrane, and Albrecht describes as vocal cords what might more correctly be regarded as beyond the limit of the cord proper. Thus he figures a coronal section (see Taf. 11, fig. 1) of the larynx of *Halmaturus giganteus*, which passes through the apex of the vocal process of the arytenoid as dividing the vocal cord, whereas it is obvious that such a section must be dorsal to the cord, more especially as he represents the vocal process of the arytenoid as being of a large size. In the next figure (Taf. 11, fig. 2), opposite the anterior third of the cord, the glands and ciliated epithelium are really above the level of the cord. It is true that glands are sometimes found in the vocal cord, but they are few in number, and are in marked contrast to the numerous glands with which the adjacent mucous membrane is provided. The epithelium in the region of the cord I have always found squamous and stratified, both in pouch and adult specimens; and in horizontal sections this epithelium is seen to pass rather abruptly into the ciliated epithelium of the inter-arytenoid portion of the glottis. Our knowledge of the minute structure of the vocal cords in the Mammalia and the relation of its structure to its function is very incomplete, but in some cases, at least where they act as an organ of voice, not only do they consist mainly of elastic fibres,

but these have become so arranged as to acquire a direction corresponding to that in which they are liable to be stretched.

Reinke (13) has recently investigated the structure of the vocal cords in the human subject, staining his sections with orcein, according to the methods recommended by Tänzer and Unna. He found that, except at the two extremities of the cords, the elastic fibres were directed parallel with one another, from before backwards. These fibres were of large size, and gave off only a few very fine lateral anastomosing branches. In a dog I have found the same general arrangement. It has been already demonstrated that in certain marsupials the vocal cords contain only a moderate amount of elastic tissue, and the fibres of this tissue branch and ramify freely in all directions between the bundles of white fibres. Reinke describes the course of the elastic fibres in man as an illustration of the structural adaptation of a tissue to its function. On the other hand, we may associate the irregular arrangement of the elastic fibres in the marsupials with the fact that their vocal cords are not liable, as in man, to frequent and tense traction in a definite direction.

Muscles of the Larynx.—The musculature of the marsupial larynx departs from the typical mammalian arrangement, owing to the union of the cricoid and thyroid cartilages leading to the more or less complete disappearance of the crico-thyroid, while a well-developed inter-arytenoid cartilage modifies the inter-arytenoideus muscle. Körner (9) gives an excellent description of his dissections of the muscles of the larynx of two adult marsupials, which he names *Halmaturus giganteus* and *H. Billardieri*. As I have made serial microscopic sections of the larynx, I am able to supplement his observations, and on a few points my conclusions differ from his. The following description is based upon a series of horizontal and a series of coronal sections of the larynx of pouch specimens of *Macropus bennettii*, supplemented by sections of an adult *Didelphys virginiana* and *Macropus robustus*.

Körner describes the thyro-arytenoideus and the crico-arytenoideus lateralis as united to form a single muscle, representing the anterior part of the internal sphincter of the larynx. There is no distinct connective-tissue septum between the two muscles, as is well seen in my coronal series of sections, but their union

is probably not more intimate than in many other mammals. In a horizontal series of sections of a pouch specimen of *Macropus*, head length 2 cm., the united muscles extended through about 50 sections; and of these 35 might be regarded as belonging to the thyro-arytenoideus, and the remaining 15 to the lateral crico-arytenoideus. The thyro-arytenoideus arises from about the lower two-thirds of the ventral aspect of the mesial part of the thyroid cartilage, and from a tendon immediately behind this common to the two muscles. Körner described a decussation of the muscular fibres across the mesial plane in this position, but this is a mistake. The fibres pass backwards and outwards between the vocal cord and the thyroid cartilage in a dorso-ventral direction, to be attached to the arytenoid cartilage. They are separated from the vocal process of the arytenoid by the vocal cord. External to this there is an area where the arytenoid cartilage is covered by loose connective tissue: only a few fibres are attached here, almost all of them being inserted more externally into the anterior part of the muscular process.

The crico-arytenoideus lateralis may be considered to commence at the level of the union of the cricoid and the thyroid. At this point the fibres of origin leave the median line, and become attached to the upper border of the cricoid just behind its union with the thyroid, some of the lowest fibres being attached to the outer surface of the lateral part of the cricoid. The muscle is inserted into the anterior aspect of the muscular process of the arytenoid immediately below and continuous with the thyro-arytenoideus. Some of the fibres turn round the outer border of the arytenoideus, to be continuous with the muscles on the dorsal aspect of this cartilage.

The action of these two muscles is essentially the same as in the human subject. Their main function, however, will be to approximate the vocal ridges of the two arytenoid cartilages, rather than drawing forward the arytenoids, and thus relaxing the vocal cords. This must be the case more particularly in the adult, where the vocal cord is very rudimentary, and the vocal process of the arytenoid, even with these muscles relaxed, is situated just behind the thyroid cartilage.

Crico-thyroid.—Körner describes this muscle as completely

absent. I can confirm this statement for that portion of the muscle which is normally developed in man, viz., the crico-thyroideus anticus, but in the series of horizontal sections of the pouch specimen of *Macropus* a small crico-thyroideus posticus was present on both sides. This muscle, often termed cerato-cricoid, has been found in the human subject by Merkel (14). Turner (15), Luschka (10), and others. I have not been able to satisfy myself of its persistence in the adult marsupials.



FIG. 8.—Horizontal section of larynx of pouch specimen of *Macropus bennettii*—head length 2 cm. c.c., c.c., cricoid cartilage; a.c., arytenoid cartilage; t.c., thyroid cartilage; l.c.a.m., lateral crico-arytenoid; k.c.a.p., posterior kerato-crico-arytenoid muscle; c.a.p.i., posterior internal crico-arytenoid muscle.

Kerato-crico-arytenoides posticus.—In horizontal sections of the larynx two distinct muscles can readily be recognised on the dorsal aspect of the cricoid cartilage. Of these, one is external to, and also partially covers the dorsal aspect of, the other. The external muscle is the kerato-crico-arytenoides. Its main origin is from the dorsal border of the large posterior or inferior corner of the thyroid cartilage; it also arises from the lower part of the adjacent portion of the cricoid. The fibres ascend in a nearly vertical direction, and are inserted into the posterior border of the muscular process of the arytenoid. Fürbringer

(16) describes this muscle as existing in several placental mammals (*Dasyprocta* and *Delphinus*).

Crico-arytenoideus posticus internus.—This muscle is smaller, and lies internal and ventral to the preceding muscle. It arises from the posterior aspect of the cricoid cartilage, reaching nearly to the mesial plane. Its fibres pass upwards and outwards, and are inserted into the muscular process of the arytenoid, just internal to the kerato-crico-arytenoideus. A few of the fibres go nearly vertically upwards, and are attached to the internal process of the arytenoid and to the inter-arytenoid cartilage. These two muscles represent the crico-arytenoideus posticus of the majority of mammals, which has become split into two parts, and its attachments modified owing to the large size of the inferior cornu of the thyroid cartilage, the slight vertical extent of the posterior part of the cricoid cartilage, the development of a large internal process to the arytenoid, and the existence of an inter-arytenoid cartilage. They will rotate outwards and pull back the arytenoid cartilage, and so dilate the glottis.

Arytenoideus.—The chief peculiarity of this muscle is that the whole or the large majority of its fibres do not cross from one side to the other, but are interrupted by the interarytenoid cartilage, into the sides of which the muscular fibres are inserted. In a pouch specimen of *Macropus* I could not detect any fibres crossing the mesial plane, but in adult specimens of *Macropus robustus*, *Macropus bennettii*, and *Didelphys virginiana* a few crossed just above the level of the interarytenoid cartilage, the main portion of the muscle, however, being attached to the sides of this cartilage. In the adult *Didelphys virginiana* some of the upper fibres of the arytenoideus extended into the lateral wall of the larynx, towards the epiglottis. They could not be traced so far as this cartilage, but ended amongst the numerous sub-mucous glands found in this situation.

All these laryngeal muscles are supplied by the recurrent laryngeal nerves. Numerous sympathetic nerve cells were found along the course of the branches of the superior laryngeal nerves, but none were observed on the branches of the inferior laryngeals supplying the laryngeal muscles.

A number of the sections referred to in this paper were made during the present summer in the Anatomical Institute of the

University of Tübingen; and I am greatly indebted to Professor A. Froriep for the generous manner in which he placed his laboratory at my disposal, and also for the loan of various memoirs dealing with this subject. I have to thank Miss Clara Patterson for the photographs reproduced in this communication.

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CONGENITAL MALFORMATION OF THE LIVER —
ABSENCE OF THE LOBUS SPIGELII, RUDI-
MENTARY QUADRATE AND LEFT LOBES, WITH
ENLARGEMENT OF THE RIGHT LOBE. By P. A.
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KAUFMANN, Ziegler and others, in recent works on pathologic anatomy, divide anomalies of the liver into two classes, congenital or acquired. The congenital malformations are of interest, as they throw light on some important problems in the morphological anatomy of the gland.

Abnormal lobulation is not very uncommon, in rare and extreme cases leading to the development of accessory livers. One or the other of the principal lobes may be abnormally small or even completely absent, in which case the other parts hypertrophy. Such malformations are not common, and have but little clinical significance.

"Variations in form occur occasionally, but they are more rare in the liver than in almost any other organ of the body. I have seen the left lobe so small as to appear a mere appendage to the right, being connected to it only by a thin and narrow isthmus. Cruveilhier records an instance in which the left lobe was attached to the right merely by a vascular pedicle about half an inch in length, the extremity of the lobe being adherent to the upper part of the spleen."¹

At a recent post-mortem at the Cook County Hospital, the following rare instance of congenital anomaly of the liver was found. The liver under consideration was taken from a man, a butcher, 53 years of age. The clinical diagnosis was apoplexy. The following is an extract from the post-mortem record:—

"There was an extensive subdural meningeal hemorrhage. There were no scars on the abdomen. The liver occupied the right half of the abdominal cavity, displacing the cæcum to the median line. There was no liver tissue to the left of the

¹ Erasmus Wilson in *Todd's Cyclopædia*, vol. iii. p. 163.

coronary ligament. The organ extended from the ensiform appendix to below the umbilicus in the median line, and stretched from thence to the right iliac fossa. From the clinical history we learned that its lower border was not palpable during life. The gland measured 32·5 centimetres from above downward, 22·5 centimetres from right to left, and 11 centimetres in thickness. It weighed 2550 grams."

The chief malformation of this liver consists in the absence or

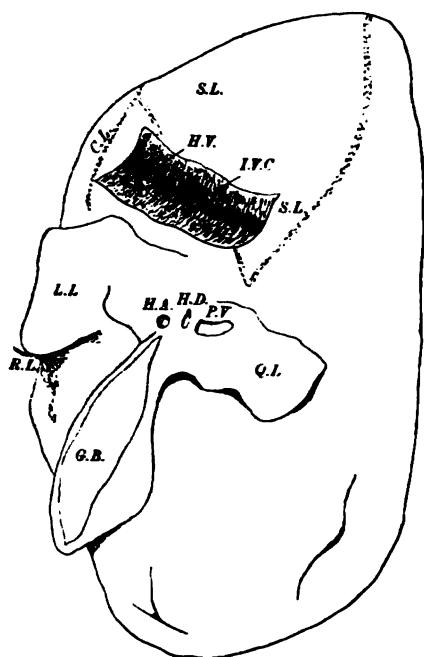


FIG.—Anomalous lobation of the liver, caudad surface. *C.L.*, coronary ligament; *G.B.*, gall-bladder; *H.V.*, opening of hepatic vein into inferior vena cava; *H.A.*, hepatic artery; *H.D.*, hepatic duct; *I.V.C.*, inferior vena cava; *L.L.*, rudimentary left lobe; *P.V.*, portal vein; *Q.L.*, accessory lobe; *R.L.*, possible rudiment of the ligamentum teres; *S.L.*, area of attachment to diaphragm.

very slight development of the left lobe, which can be recognised as a process of tissue given off from the left border of the right lobe at about the junction of the middle with the upper third. This process of tissue measures about 5 centimetres in length, 3 to 4 centimetres in width, and from five-eighths to 1 centimetre

in thickness. It is not separated from the main part of the liver, the longitudinal fissure and falciform ligament being absent.

The right lobe is enlarged, weighing, as stated above, 2550 grams. It was suspended from the diaphragm by the coronary ligament on the left, and on the right by a triangular fibrous attachment on the upper part of its posterior surface. These are its only points of attachment.

The anterior or cephalad surface is convex and smooth. The right border is smooth and somewhat rounded. The lower border is also smooth and rounded, and extended, as stated above, from the right iliac fossa to the median line below the umbilicus. The upper border presents, to the left the coronary ligament, and to the right the triangular fibrous attachment to the diaphragm. This border must have been in close contact with the diaphragm. The left border is somewhat irregular. The undeveloped left lobe and the gall-bladder project over this border, which must have been in contact with the intestines below and with the pyloric end of the stomach above. The posterior or caudad surface presents much the same appearance as does that of a normal liver, if we except the shape, the absence of the lobus spigelii, and the slight development of the accessory and left lobes.

Above and to the left is the opening of the hepatic vein into the inferior vena cava, which has been split open longitudinally (see figure). The cut ends of the hepatic artery and duct and the portal vein are to be noticed near the centre, a little to the left of it. The transverse fissure is but poorly developed. The gall-bladder extends forward, downward, and to the left, and rests in a depression of the liver substance. Two slight inconsequential fissures are to be noticed, occurring near the lower border of this surface. The ligamentum teres appears as a fibrous cord below the rudimentary left lobe. There is no trace of a ductus venosus.

Microscopic sections were made, one from the undeveloped left lobe and one from the right lobe. The former shows the left lobe to be composed mainly of fibrous tissue, with some areolar tissue, and here and there streaks of liver tissue, the cells of which were small and compressed, though otherwise normal. Bile-ducts are not present. The section from the right lobe shows beginning cirrhosis, diffuse round-cell infiltration, together with the

formation of new vessels, also some increase in the connective tissue, and consequent slight atrophy of the liver cells proper. The last three changes are not very strongly marked.

From this description it appears that we have here a malformation of the liver, consisting in the absence of the lobus spigelii, and very slight development of an accessory, possibly a caudate lobe, and of the left lobes, and a marked enlargement of the right lobe. How much of the enlargement of the right lobe is purely hypertrophic in its nature and how much is due to the beginning cirrhosis cannot be definitely stated, but surely some degree of compensatory hypertrophy is present.

That this anomalous configuration is congenital in origin there can be no doubt. Note the absent spigelian lobe, the smoothness of the surface of the left lobe and of the entire liver, the absence of any scar in the abdominal wall, and of cicatricial tissue in the liver.

A study of this case brings home the fact that such malformations, though infrequent, might lead to serious mistakes in clinical diagnosis, and that they are therefore worthy of consideration.

Among the many congenital anomalies of the liver described in the literature at our command, any case the exact counterpart of the one here reported was not met with. It is self-evident that the great enlargement of the right lobe, which is probably, to a large extent, hypertrophic in its nature, would naturally be interpreted by the clinician as wholly due to some acquired morbid process. Hence it seems that in the differential diagnosis of enlargements and growths of the liver, those that may be connected with congenital malformations of the organ certainly deserve to be borne in mind.

AN INTERESTING CASE OF CONNECTION BETWEEN
THE LUNGS AND SYSTEMIC CIRCULATORY SYSTEM
AND OF AN ABNORMAL HEPATIC BLOOD
SUPPLY IN A FROG (*Rana temporaria*). By GEO.
P. MUDGE, A.R.C.S. Lond., *Demonstrator in Biology at the
London Hospital Medical College.*

THE animal which forms the subject of this paper was undergoing dissection in a class at the Polytechnic Institution, Regent Street, London, when I observed that there existed a vascular communication of some kind between the apex of the left lung and the spleen. Preserving it at once, I afterwards injected the arterial system from the truncus arteriosus with carmine gelatine, and the portal system from the portal vein with Grubler's blue.

Upon examination, the apices of both lungs were found to be in connection with arterial and venous vessels, which in their turn appeared to be connected with the vascular supply to the alimentary canal, and the spleen was seen to be slightly misplaced (fig. 2, *s.p.*), for instead of being situated dorsad to and at the level of the anterior extremity of the large intestine, it was considerably more anterior, and lay at the level of the junction of the duodenum with the ileum.

A detailed examination of the arteries to the alimentary canal revealed nothing abnormal except for the vessels passing to the lungs and liver. When the liver and ileum were reflected to the left, and the dorsal aorta had been exposed by dissection, the coeliaco-mesenteric artery was seen to arise as usual from the point where the systemic arches united to form the dorsal aorta, and running backwards and slightly to the left it divided (fig. 1) into two branches, viz., the coeliac (*c.*) and superior mesenteric (*m.*) arteries, the former proceeding to the head of the pancreas, and the latter passing backwards towards the intestine.

Shortly after the coeliac artery reaches the pancreas (fig. 1) it turns suddenly upon itself, and forming a sharp bend, runs laterally to the inner side of the right lung and enters it a little

way above the apex, where it breaks up into a meshwork of capillaries, which are distributed to both faces of the lung. To which portion of the lung this capillary plexus is restricted, if it be confined to any particular area at all, I was unable to determine by injection only; but it so happens that in this particular frog some of the blood-vessels are densely pigmented. Especially is this so with the veins of the lungs and ileum and the factors of the superior venæ cavæ, and by means of it the

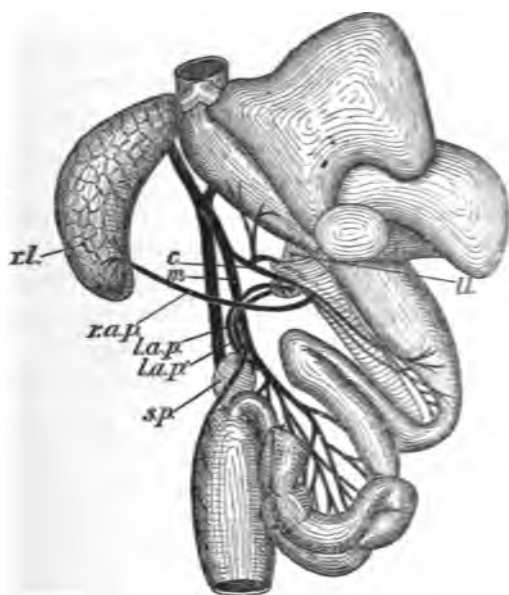


FIG. 1.—*Arterial System*—twice nat. size. The liver and ileum reflected to the left side, and the spleen delineated in a slightly lowered position. *c.*, celiac artery; *m.*, superior mesenteric artery; *l.a.p.*, left anterior accessory pulmonary artery; *l.a.p'*, left posterior accessory pulmonary artery; *r.a.p.*, right accessory pulmonary artery; *l.l.*, left lung; *r.l.*, right lung; *s.p.*, spleen.

smallest factors of the pulmonary veins can be followed, as also those of the veins ramifying in the apices of the lungs, and a very superficial examination allows one to trace an anastomosis between the two.

It will be observed, upon reference to fig. 1, that that which from its size appears to be the main branch of the celiac artery

constitutes the vessel going to the right lung,¹ and which I propose to term the *right accessory pulmonary artery*, as distinct from the other branches of the cœliac which pass to the stomach and are much smaller, two in number, and run closely parallel with each other. In three respects, therefore, the cœliac is abnormal, viz., in the distribution of its main branch to the lung, in the two branches supplying the stomach running parallel with each other instead of diverging, and in that they are small branches, and not two large ones formed by division of the main trunk.

The left lung, unlike the right, is supplied by two arteries, both of which arise from the superior mesenteric. The anterior (fig. 1, *l.a.p.*) of these arises very close to the origin of the branch supplying the large intestine,—so near, indeed, that the two vessels might almost be regarded as arising in common. I propose to call this the *anterior left accessory pulmonary artery*. It bends round towards the left, and reaching the dorsal surface of the apex of the left lung, breaks up into a capillary plexus.

The other artery, *posterior left accessory pulmonary artery* (fig. 1, *l.a.p'.*), arises from the superior mesenteric at a point posterior to that just described from the branch which supplies the ileum. Thence it turns to the left, and running parallel to the anterior accessory pulmonary artery, reaches the apex of the left lung, upon the ventral surface of which it terminates in a capillary plexus. The apex of the left lung is therefore supplied by two arteries, one to the dorsal and the other to the ventral surface.

When the hepatic portal system was injected from the portal vein, two veins (fig. 2, *l.v.p.* and *r.v.p.*), one on either side, running closely parallel with the accessory pulmonary arteries, became visible. I propose to call these *right and left accessory pulmonary veins*.

The *left accessory pulmonary vein* (fig. 2, *l.v.p.*) arises from the apex of the left lung, whence it runs obliquely inwards and backwards, and reaching the spleen, passes over its dorsal surface, and enters the main portal trunk close to the entry of the factor from the large intestine. I made a very careful examin-

¹ Cf. Milne Edwards, *Leçons sur La Physiologie et L'Anatomie Comparée de L'Homme et des Animaux*. Tome 3. Paris.

ation of this vein where it is in contact with the spleen, and failed to detect any communication with that organ.

The *right accessory pulmonary vein* (*r.r.p.*) arises from the apex of the right lung, and passing inwards and backwards, enters the main portal vein a little higher on the side opposite the left accessory.

In other respects the portal vein is normal, with the exception that there appears to be one more gastric factor (fig. 2, *g.a.*) than usual, which enters the portal vein independently of the others.

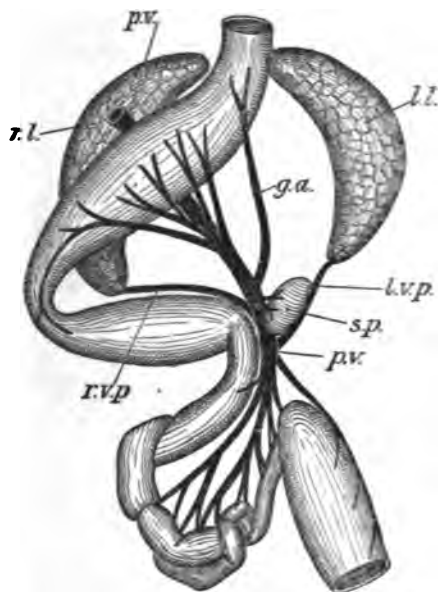


FIG. 2.—*Portal Venous System*—twice nat. size. The stomach and duodenum reflected to the right. *g.a.*, accessory gastric vein. *l.v.p.*, left accessory pulmonary vein. *r.v.p.*, right accessory pulmonary vein. *r.l.*, right lung. *l.l.*, left lung. *r.l.*, right lung. *p.v.*, portal vein.

As already mentioned, the factors of the pulmonary and accessory pulmonary veins are extensively pigmented, wherefore their course and relationships may be readily followed (*ante*, p. 1).

Dealing with the right lung first, we find that the right accessory pulmonary vein, as determined by the presence of pigment at the apex of the lung (fig. 3), receives two venules, one of

which (*a.*) comes from the outer border and enters into a direct anastomosis with a venule (*a'.*) of the pulmonary vein; the other, (*b.*), coursing along the inner side, enters into similar relation with another factor (*b'.*) of the same vein. The factors (*a.* and *b.*) of the accessory pulmonary vein give off laterally several smaller vessels, which enter into connection with similar vessels forming the pulmonary vein, and their disposition is such as to leave little doubt that the capillary plexus of the two, viz., the pulmonary and accessory pulmonary vein, become merged. On the dorsal surface of the lung the arrangement is the same, the two factors of the accessory pulmonary vein anastomosing with those of the pulmonary vein as on the ventral surface.

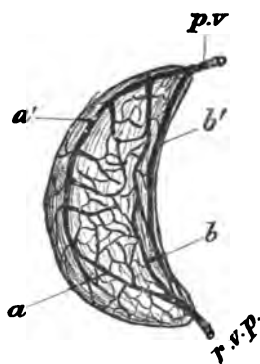


FIG. 3.

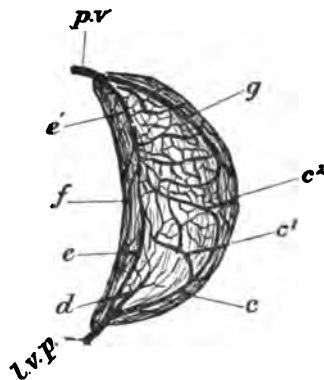


FIG. 4.

The right lung (fig. 3) and left (fig. 4), showing anastomosis between the pulmonary and accessory pulmonary veins. *p.v.*, pulmonary vein. *l.v.p.*, left accessory pulmonary vein. *r.v.p.*, right accessory pulmonary vein. Twice nat. size.

The anastomosis between the accessory pulmonary and pulmonary veins of the left lung is similar to that of the right, but differs from it in certain details. On the right side the anastomosis is direct, viz., the factors of either vein directly unite, while on the left the factors (fig. 4), for the most part, are connected by an intermediate series of exceedingly small vessels. The left accessory vein at the point where it leaves the lung arises from four factors, three of which arise from the ventral surface, the other from the inner dorso-lateral.

The outermost of these (fig. 4, *c.*) runs along the outer border

of the lung, as an almost unbranched vessel, for about a fifth of the length of the lung, when it receives two smaller factors (c^1 . and c^2 .), which pass obliquely across the width of the lung, and at the same time anastomose with each other. The meshwork of minute venules which pour their blood into the more anterior (c^2 .) of the two are connected with a factor (g .) of the pulmonary vein, so that at this point an anastomosis between the pulmonary and accessory pulmonary vein takes place.

The two inner factors (d . and e .) anastomose with one another, and anteriorly with the outer ones (c^1 . and c^2 .) also, and in addition are connected with the factor (f .) from the dorsal surface. Of these two inner factors, the inner (e .) is by far the more prominent, and runs along the inner border of the lung, entering into an anastomosis with a factor (e' .) of the pulmonary vein.

It will thus be seen that the blood from the posterior third of either lung is carried away by factors of the *accessory pulmonary veins*, and that they receive their blood, in part at least, from the *right* and *left accessory* pulmonary arteries. Since the lungs of snakes (*ante*, p. 4) are partly supplied with blood from the systemic circulation, and are vesicular in the portion thus supplied, it becomes interesting to ascertain the structure of the lung of this remarkable frog. Opening the left lung, I find it to be reticular over its whole surface, and the portion supplied by the abnormal vessels to be in no way different from the rest.

It follows, from the relation of the accessory pulmonary veins to the portal vein, that the liver was probably supplied with arterialised blood *via* the portal vein, wherefore the greater interest attaching to the hepatic supply.

Searching for the hepatic artery, I failed to find it in the usual position, but found instead that the liver (fig. 5) was supplied by a vessel which arose from the left pulmonary artery just immediately before that reached the root of the left lung.

This abnormal hepatic artery enters the larger division of the left lobe of the liver at its left anterior corner. Unfortunately it could not be followed further, owing to injury to the left aortic arch. The blood which reached the liver by this course was venous, since it came from the pulmonary artery; and the only source from which that organ received its arterial supply was from the portal vein, as already described.

In seeking for a parallel to the remarkable conditions herein described, my attention was directed by Professor Howes to the snake's lung, well known to receive branches of the systemic blood-vessels; and on comparison it at once became obvious that the variation above described in the frog had been modelled, so to speak, upon the Ophidian plan, as described by Hyrtl and Calori. Indeed, so close is the resemblance that, making allowance for the fact that in the snake only one lung is fully developed (5), and that the liver is an elongated body closely applied to the inner side of that, we have fundamentally the same arrangement. As is well known, the lung of snakes is

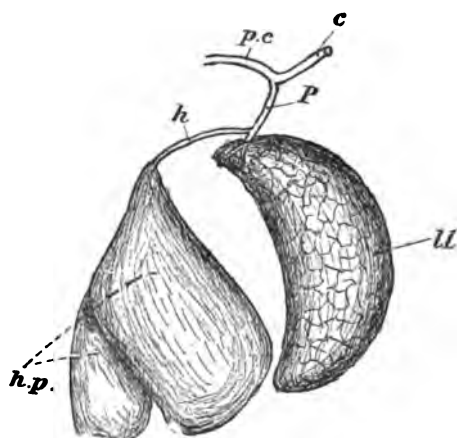


FIG. 5.—The left lobe of the liver (*h.p.*) and left lung (*l.l.*), showing arterial blood supply. Twice nat. size. *c.*, cutaneous artery. *h.*, abnormal hepatic artery. *P.*, pulmonary artery. *p.c.*, pulmo-cutaneous aortic arch.

composed of two portions, an anterior reticulated and a posterior vesicular portion. Hyrtl (1) states that in Ophidia the primary pulmonary artery is restricted to the reticular part of the lung, while the vesicular part is supplied by a series of small arteries (secondary pulmonary arteries) which arise from the aorta. In addition, other secondary pulmonary arteries arise from the arteries of the liver, œsophagus, and stomach, the blood being subsequently returned to the portal vein by a series of corresponding venous trunks.

Three years later than Hyrtl, Calori (2) further showed that the snake's pulmonary artery, upon reaching the lungs, divides

into two branches, an anterior and posterior, the latter of which further divides into right and left branches, the right branch, according to his description, communicating with the liver, but according to his figure (figs. 1, 12, and 5) directly entering the hepatic artery. Both right and left branches anastomose with the 'rete vasorum' of the lung.

He further showed that of the two principal factors of the pulmonary vein, viz., an anterior and a posterior, the latter stands related to the portal vein by "numerous secondary pulmonary venulæ," these, on the one hand, opening directly into the portal trunk, and on the other, entering into communication with the posterior factor of the pulmonary vein by means of the capillary network of the reticulated portion of the lung. In addition, the secondary pulmonary venulæ sometimes unite to form 'principal veins' before entering the portal vein.

The blood from the vesicular portion of the lung is also, according to Calori, returned to the portal vein by means of a vein which, running over the surface of the liver, receives secondary pulmonary venulæ from that portion of the lung.

Combining the observations of Hyrtl and Calori, we find that in *Ophidia* the arrangement of the arteries and veins is in many respects similar to that of the abnormal frog herein described. For instance, the hepatic artery (fig. 5, *h.*) arising from the pulmonary artery is almost the counterpart of the right branch of the posterior division of the corresponding artery in *Ophidia* described by Calori; while the *right accessory pulmonary artery* (*r.a.p.*, fig. 1) arising from the coeliac artery and passing to the right lung, apparently corresponds very closely to one of the series of arteries which arise from the hepatic, œsophageal, and coeliac arteries in *Ophidia*, as described by Hyrtl. That the two *left accessory pulmonary arteries* (*l.a.p.* and *l.a.p'*, fig. 1) which arise from the superior mesenteric should not be represented in *Ophidia*, is not surprising when we remember that in them the left lung, if developed at all, is rudimentary (5 and 6).¹

Comparing the condition of the veins of this frog with that of the *Ophidia*, the same general similarity is even more apparent. The venulæ (figs. 3 and 4, *a.* to *f.*) opening into the *accessory pulmonary veins* appear to correspond to the 'secondary pulmonary

¹ Cf. Butler, 5 and 6.

veins' described by Hyrtl, for in both cases they pass from the posterior portion of the lung to the portal vein, and carry to it the blood brought to the lung by the 'secondary pulmonary arteries.' A comparison of figs. 3 and 4 with fig. 1 in Calori's paper, taken in conjunction with the description in both cases, will show how similar they are. Calori figures a capillary plexus upon the reticulated portion of the lung, connected on the one side with the two main factors of the pulmonary vein, and on the other by means of secondary pulmonary venulæ with the portal vein, precisely as in the frog now described, where the portal and pulmonary veins are in connection by means of the capillary plexus of the lungs. The venules (figs. 3 and 4, *a. to f.*) obviously are equivalent to the 'secondary pulmonary venulæ' of Calori, while the *accessory pulmonary veins*, which receive the venules, may be regarded as the 'principal veins' of Calori (*ante*, p. 4) very much lengthened, in adaptation to the greater distance of the portal vein from the lungs.

Hyrtl stated that the plexus derived from the branching of the primary pulmonary artery anastomoses with that derived from the secondary pulmonary arteries arising from the aorta. I am able to show that in this frog the same anastomosis occurs, since the injection of the right lung from the truncus arteriosus was so perfect that the *accessory pulmonary vein* of that side was injected red for about the length of a millimetre at the point where it left the lung. That this was not due to the injection having passed through the capillaries from the *right accessory pulmonary artery* is negatived by the fact that although the *left accessory pulmonary arteries* were quite as well injected as the right, owing to injury of the left aortic arch the capillary plexus of the left lung was not well injected; and although the arterial system was injected before the venous, no such injection of the left accessory pulmonary vein could be observed as was seen in the right.

Whether the close correspondence between the remarkable condition herein described as abnormal for the frog and that apparently normal for certain Ophidians be indicative of anything more than mere coincidence, further investigation can alone determine.

In conclusion, I would desire to acknowledge my indebtedness

to my former teacher, Professor G. B. Howes, LL.D., F.R.S., for kind assistance willingly rendered.

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A CASE OF UTERUS MASCULINUS—TUBULAR HERMAPHRODITISM—IN THE MALE, WITH SARCOMATOUS ENLARGEMENT OF AN UNDESCENDED TESTICLE. By A. PRIMROSE, M.B., C.M. Edin., *Professor of Anatomy in the University of Toronto.* (PLATE I.)

A YOUNG man, 32 years of age, presented himself at the clinic at St Michael's Hospital, suffering from a large abdominal tumour, the nature of which was obscure. An attempt was made to remove the growth by operation. The individual possessed all the features of a well-developed man; the only abnormal conditions noted were that the testicles were undescended, and that a large tumour situated in the lower portion of the abdomen, on the left side, filled up the left iliac fossa and extended above the umbilicus.

The history states that the left testicle had never descended wholly into the scrotum, but that on several occasions during the man's lifetime it had occupied a position near the external abdominal ring, where it could be palpated. For three months previous to admission, however, the testicle had not presented itself, and during that time the abdominal tumour developed. Under the anæsthetic, at the time of operation, the right testicle could be defined by palpation through the abdominal wall in the right iliac fossa. The penis was well formed, and the urethra and meatus urinarius were normal. The individual possessed a beard, and his voice was of the male type. There had never been any doubt as to his sex: he was in every respect, as far as external appearances were concerned, a well-developed man, save in the condition of cryptorchism. It may be noted that there had never been any history of menstruation. It was found impossible to eradicate the tumour, and the man died a few hours after the operation.

A complete post-mortem examination could not be obtained, but the pelvic organs were examined and removed through the

abdominal incision, and the following conditions were subsequently found.¹

The bladder and prostate were normal in every respect, save that the opening of the sinus pocularis was perhaps slightly anterior to the point where it usually opens on the floor of the prostatic urethra. The opening referred to was of the normal size and appearance. It was found, however, to communicate with a structure which lay between the rectum and the bladder (Pl. I. fig. 1). This, on further investigation, proved to be a well-formed vagina and uterus. The uterus (including the body and cervix) was 7 cm. in length, and this was continuous with a vagina 4.6 cm. long. The width of the cavity of the uterus at the fundus was 1.5 cm., and in the middle of the uterine body .6 cm., whilst the thickness of the uterine wall was .4 cm. The cervix measured 2 cm. in length; its cavity was spindle-shaped, and measured in its centre (its widest part) .75 cm., being .6 cm. at the internal os and 5 cm. at the external os in diameter. The vagina opened into the prostatic urethra at the point mentioned above by a slit-like aperture .3 cm. long. The prostate measured 2.5 cm. from base to apex, with a transverse diameter at the base of 3 cm., whilst it was 2 cm. thick from before backwards.

The uterus was characteristic in shape and appearance; the cavity of the body expanded towards the fundus, and terminated on each side in a rudimentary Fallopian tube; each tube could be traced for the distance of about 1 cm., and the uterine mucosa was continued into it. The body of the uterus was definitely marked off from the cervix, the latter possessing a remarkably well-developed series of plicæ palmatæ (figs. 1 and 2). The vaginal wall was thin, and possessed a somewhat rugose condition of the lining mucous membrane. The vagina tunnelled the lower portion of the prostate before opening into the prostatic urethra.

A careful search was made for the seminal vesicles, but no trace could be found of these structures, nor was any indication of the vasa deferentia discovered. It should be remarked, however, that the difficulty of defining these structures was greatly

¹ The post-mortem examination was made by Dr R. J. Dwyer, of St Michael's Hospital.

increased in consequence of the fact that the relations had been considerably disturbed; the post-mortem examination was hurriedly performed, and the specimen had not been examined until after it had been removed from the body; thus, for example, the right testicle was removed separately, and was entirely separated from its surroundings, so that its precise connections could not be determined. The right testicle was 3 cm. in length and 2 cm. in width. A microscopic examination was made of this structure, and a normal condition of the seminiferous tubules determined. Smooth muscle-fibre and uterine glands were found, under the microscope, in the uterine wall; a section of the tumour exhibited the characteristic features of a round-celled sarcoma. One could find no trace of a left testicle; apparently it had undergone sarcomatous development, and thus the tumour was accounted for.

The bladder was normal, and the ureters opened in the usual situations. They passed back one on either side of the vagina, where they had been severed about 5 cm. from the bladder.

Cases of uterus masculinus have been recorded from time to time, illustrating conditions very like those existing in the preparation at present under consideration.

Langer¹ in 1855 reported a case occurring in a man 63 years of age, who died of phthisis. He had been thirty years married, but was childless. In this man neither testicle had descended; he suffered from hernia on the left side, and behind the hernia, in the inguinal canal, the left testicle could be indistinctly felt. On post-mortem examination, a structure was found between the bladder and the rectum, which proved to be a uterus, with its appendages. The whole structure measured 7 inches in length, and was divided into two portions, the lower (smaller) one representing the vagina, whilst the upper portion represented the uterine body and cervix. The cervix was distinguished from the body of the uterus by the presence of the arbor vitæ indistinctly marked, whilst at the external os the vagina was separated from the cervix by a partition, which completely obliterated the lumen at that point. From the horn of the uterus on each side proceeded a well-developed fallopian tube, ending in fimbriæ. In each ligamentum latum, in the situation occupied in the female by the ovary, was a testicle. The two testicles were about equal in size; vasa efferentia passed into an epididymis, which in turn terminated in a vas deferens. The vasa deferentia passed in the ligamentum latum to the side of the uterus and entered the vaginal wall; after travers-

¹ *Zeitschrift der Kais. kön. Gesellschaft der Aerzte zu Wien*, xi. Jahrgang, 1855, p. 422.

ing these for a considerable distance, they opened near the vaginal orifice, as the latter appeared in the prostatic urethra. There were no seminal vessels, but the vasa deferentia became markedly convoluted, and exhibited ampullæ before entering the vaginal walls.

Langer¹ has placed on record a second case in which a well-developed uterus was found in the body of a young soldier. The external organs were those of a normal male. The uterus measured 8 cm. in length. The vasa deferentia were present. Each vas presented ampullæ along the lateral aspect of the vagina. Two small seminal vesicles were present, opening on each side with the vas into a common ejaculatory duct. The ejaculatory ducts opened into the vagina immediately before the latter terminated by opening into the prostatic urethra. The body of the uterus was readily distinguishable from the cervix by the plicæ palmatæ, which were observable in the mucous membrane of the latter. The vagina tunneled the lower part of the prostate, and its opening in the prostatic urethra resembled in appearance and size the opening of the prostatic sinus as it appears under normal conditions. The testicles were undescended, and lay in the lateral ligaments of the uterus.

Stonham² describes a somewhat similar condition of uterus masculinus occurring in a child 9 years of age. The child was admitted to hospital for the purpose of operating on a right inguinal hernia. The child died after the operation, and was found to present the condition of uterus masculinus. The external organs were those of a normal male, except that there was perhaps a slight degree of hypospadias. The uterus and vagina were readily distinguishable from one another, the plicæ palmatæ in the cervical portion of the uterus being well developed. There were no seminal vesicles; the testicles lay in the lateral ligaments of the uterus, and in each case the epidymis could be defined, connected with which was the vas deferens; the latter structure was traced as far as the wall of the uterus, where it became so small that it was impossible to trace it further. The testicles, which occupied a position similar to that of the ovaries in their normal relation to the uterus, were examined microscopically, and their true character thus determined beyond doubt.

Willett's³ case was that occurring in a man who was married, and is said to have had two children. The testicles were undescended; the penis was well developed. The uterus was hollow, but no lumen could be found in what appeared to be the fallopian tubes; these structures were apparently solid cords. There was no cervix, but a well-marked vagina was distinguishable. The prostate was normal.

¹ "Ein neuer Fall von Uterus Masculinus bei Erwachsener," von Prof. C. Langer in Wien, *Archiv für Anatomie und Physiologie*, Anatomische Abtheilung, 1881, p. 392.

² "Case of perfect Uterus Masculinus, with perfect Fallopian Tubes and Testes in the Broad Ligament," by C. Stonham, *Trans. Path. Soc. Lond.*, vol. xxix., 1888, p. 219.

³ "Transverse Hermaphroditism in the Male," by Edgar Willett, *Trans. Path. Soc. Lond.*, vol. xlv., 1894, p. 102.

The epididymis was found and the vas deferens; the latter was traced to the side of the uterus, and became lost in the uterine wall; the opening into the vagina was sought for, but could not be found. There were no seminal vesicles.

Cases of a somewhat similar nature, looking at the matter from the embryological standpoint, have been reported where the Muellerian ducts have persisted, but, although considerably developed, have remained separate, not having fused to form the uterus and vagina.

Boogaard¹ describes this condition in a man 66 years of age, who died of Bright's disease. There existed what were described as supplementary canals to the ureters, one on each side. These structures were of the following dimensions:—The right 3·5 cm. in circumference, and the left 7·8 cm. in circumference. They were entirely distinct from the ureters, and were not connected with the pelvis or calices of the kidney. They were somewhat dilated at the upper end into a sac 7·5 to 8·5 cm. in diameter. The two canals appeared to be united below, but their cavities remained distinct throughout. They opened in the middle line into the prostatic urethra upon the colliculus seminalis. There was no orifice of a prostatic utricle, and the ejaculatory ducts opened into the prostatic urethra by two separate orifices. The asymmetry in size of the two canals in this man was remarkable. Boogaard contrasts the condition with the atrophy of one of the canals occurring normally in female birds.

Dr E. Martin² reports a case occurring in an individual of the female type. The condition was found in a fœtus born dead at the eighth month. The pelvis was poorly developed, and there seemed to be an entire absence of the normal pelvic organs. The perineal muscles were ill developed, and there was no opening of anus, vagina, or urethra. The existence of a genital fissure led Martin to believe that there was a tendency to the female sex, but this sexuality did not extend to the internal organs. A large sac was found in the abdominal cavity, forming a tumour of large dimensions. This proved to be the urinary bladder, which had been tapped before birth in order to overcome the insurmountable impediment offered by it to the completion of labour. Into this bladder two ureters opened, and in addition two other structures of similar appearance opened there. The ureters were 15 to 16 cm. long. The two other canals punctured the vesical wall obliquely, like the ureters; they were dilated for from 2 cm. to 3–4 cm. from the bladder. At the level of the kidneys they were reduced to a mere filament, and were lost in the cellular perirenal tissue, and ceased to be permeable. These canals

¹ "Persistance du canal de Müller chez l'homme adulte," par J. A. Boogaard, *Jour. de l'Anat. et de la Phys.*, 1877, p. 200.

² "Un cas de persistance des canaux de Müller," par le Dr E. Martin, *Jour. de l'Anat. et de la Phys.*, 1878, p. 21.

were undoubtedly the canals of Müller. There was a complete absence of genital organs.

Remy¹ describes a condition of a somewhat similar character in a child 6 years old. The child had difficulty in micturition and a distended bladder. Thirty hours after death the ureters were found dilated to the size of the small intestine. Accompanying the right ureter was a supplementary structure, which did not communicate with the kidney, but took origin at the level of the suprarenal capsule, and appeared to be at that point connected with a small group of cysts; these were transparent in character, and were regarded by Remy as the remains of the Wolffian body. This structure passed down with the ureter and entered the base of the bladder. It contained a whitish fluid, resembling purulent urine in appearance. The upper extremity was found to terminate in a *cul-de-sac* among the cysts. The lower extremity passed through the muscular wall of the bladder and opened into the prostatic utricle. No abnormal canal was found on the opposite side. The vasa deferentia and the ejaculatory ducts were normal, as were also the prostate and the urethra.

A very interesting paper on the subject of hermaphroditism has been published recently by Siegenbeek van Heukelom in Ziegler's *Beiträge zur Path. Anat.* The author reports a case, and discusses the whole subject of the occurrence of hermaphroditism in man. The case which he describes² is that of a young man who was operated upon by Guldenarm in Rotterdam, for what was supposed to be an irreducible omental inguinal hernia which existed on the left side. The left testicle was in its normal situation in the scrotum, but the right testicle had not descended. The penis was normal. The structure found in the hernial sac proved to be the left horn of a bicornuate uterus. The uterus was removed plus the appendages of the right side, and the specimen thus obtained was very thoroughly examined. The existence of the prostate was apparently not determined, and the precise connections of the uterus and vagina with the bladder were of course not made out, as they were severed during the operation. The cervix uteri presented the characteristic plicæ palmate, and almost immediately beyond the cervix two uterine horns diverged from one another, nearly at right angles to the axis of the cervix; these, in turn, appeared to be continuous with structures representing the fallopian tubes. The left testicle had been left in the scrotum, its connections with the uterus having been severed. On the right side there existed in the ligamentum latum a well-developed testicle. The testicle was found to be continuous with an epididymis, which communicated with a vas deferens; the last-named structure was traced towards the lateral aspect of the uterus and vagina, where it had been severed.

¹ "Sur l'utricule prostatique et le canal de Müller chez l'homme," par M. le Dr Ch. Remy, *Jour. de l'Anat. et de la Phys.*, 1879, p. 175.

² "Ueber den tubular und glandular Hermaphroditismus beim Menschen," von Prof. Siegenbeek van Heukelom, *Beiträge zur Path. und zur Allgem. Pathologie*, Ziegler, Band 23, Heft 1, p. 144.

during the operation. A careful microscopic examination was made of the various parts of the preparation: uterine glands were found in the mucous membrane of the body of the uterus, whilst ciliated epithelium was discovered lining the fallopian tube.

The histological characters of the epididymis, vas deferens, and testicle were normal. Two small bodies were identified as being respectively the organ of Giralde's and the hydatid of Morgagni. The former (the organ of Giralde's) was a small pedunculated structure, and appeared to be connected with the epididymis, whilst the hydatid of Morgagni was a ribbon-like appendage without a pedicle, and appeared to be directly continuous with the fallopian tube. The author considered that he was able to demonstrate conclusively with this preparation that the hydatid of Morgagni was in reality the persisting extremity of the Muellerian duct, supporting the view which has already been put forward by Fleischl and Waldeyer.

Cases of so-called 'true hermaphroditism' occurring in man are found recorded in literature. In a large number of these, microscopic examination was not made of the glandular organs, and we must therefore exclude these at once from the list, as the evidence is wholly inadequate. It must be understood that by 'true hermaphroditism' we mean a condition in which there exist in the same individual an ovary and a testicle. This condition is what is known by the French authors as 'glandular hermaphroditism,' as distinct from 'tubular hermaphroditism,' the latter term being reserved to describe cases similar to those already quoted in this paper, and to the case now recorded by me, *i.e.*, cases in which both the Muellerian and the Wolffian ducts persist in the same individual.

A brief reference may be made to those cases described as examples of true hermaphroditism in which a microscopic examination was made.

Heppner¹ describes a case of hermaphroditism occurring in a two months old child. The child was a hypospadiac male, the bladder and prostate were normal, but a completely developed uterus and vagina existed, the arbor vitæ of the cervix being present. The vagina opened into the urethra in front of the prostate. On each side, in the ligamentum latum, were two bodies, one of which Heppner believed to be an ovary, the other a testicle. The fallopian tubes, with their fimbriæ, were well developed, and the ovary, which was attached by an ovarian ligament to the uterus, was surmounted by

¹ "Ueber den wahren Hermaphroditismus beim Menschen," von Dr. C. L. Heppner in St Petersburg, *Reichert's Archiv fuer Anat. Phys.*, 1870, p. 679.

the parovarium. There was no vas deferens, nor was there an epididymis. In discussing the merits of this case, Siegenbeek van Heukelom considers that the structure described by Heppner as testicle is not proved to be such: the histological characters, as figured by Heppner, are, in his opinion, not sufficiently characteristic of testicular tissue.

Ziegler¹ figures a case put on record by Obolonsky.² This occurred in a child 12 years old. The external organs were so malformed that it was difficult to distinguish male from female parts. There was a fully-formed uterus and vagina. In the right broad ligament was a testicle, with an epididymis and a vas deferens, also a rudimentary fallopian tube. On the left side was an ovary suspended by an ovarian ligament, and above this a fallopian tube. Siegenbeek van Heukelom again questions the evidence of true hermaphroditism in Obolonsky's case. It would appear that the preparation was in existence twenty-one years before Obolonsky undertook the histological examination, and the details of histological structure were not sufficiently well preserved to determine the true nature of the glandular elements with absolute certainty.

Schmorl³ records a case occurring in an individual 22 years of age, who was admitted to the hospital for the purpose of being operated upon for hypospadias. The scrotum was rudimentary, and the testicles had not descended. The bladder and prostate were normal, but he had a well-developed uterus and vagina, the latter opening into the prostatic urethra. The cervix uteri exhibited the plicæ palmatæ. There were two testicles, one on each side. On the right side was, in addition, a structure which Schmorl described as an ovary. The histological characters were evidently sufficiently well marked to prove beyond doubt the nature of the two structures described as testicles, but Schmorl considered the ovary to present a structure which he called 'embryonic.' On this account, Siegenbeek van Heukelom questions the accuracy of Schmorl's conclusion in regard to the ovarian nature of the body exhibiting embryonic characters.

Blacker and Lawrence⁴ have placed on record the description of a case which was observed in a child born dead at 8½ months.

¹ *Lehrbuch der allgem. Path. und der pathologischen Anatomie*, Ziegler, Band I, p. 528.

² "Beiträge zur path. Anat. des Hermaphroditismus," *Archiv für Heilkunde*, Band 9, p. 211, 1888.

³ "Ein Fall von Hermaphroditismus," von Dr G. Schmorl, *Virchow's Archiv für Path. Anat.*, Band 113, p. 229, 1888.

⁴ "A case of true unilateral Hermaphroditism, with ovotestis, occurring in Man, with a summary and criticism of the recorded cases of true Hermaphroditism," by G. F. Blacker, M.D., etc., and T. W. P. Lawrence, M.B., etc., *Transactions of the Obstetrical Society of London*, vol. 38, p. 265, 1897.

Note.—In this paper by Blacker and Lawrence may be found a summary of 28 cases, collected from the literature, and described as instances of true hermaphroditism.

The external genitals were described as being of a doubtful character, but apparently they approached closely the female type. There was a uterus and vagina, and fallopian tubes, terminating with fimbriæ. The vagina opened into the urogenital sinus; there was no prostate. In the right broad ligament was an ovary, and on the left side a testicle, with an appendage which, on histological examination, was considered to be an ovary. A vas deferens and an epididymis existed on the left side. There seemed to be no doubt whatever regarding the contention of the authors that there was present a right and a left ovary. But the character of the structure described as a testicle has been questioned by Siegenbeek van Heukelom, who considers it very doubtful. He looks upon the case as an example of unilateral tubular female hermaphroditism, the epididymis and the vas deferens being well developed on the left side.

When one examines the literature on the subject of hermaphroditism, one finds that there has always existed a certain amount of doubt as to the possibility of the existence of true hermaphroditism in man. Sir J. Y. Simpson's classical article on the subject¹ was very exhaustive at the time it was written. Since the appearance of his treatise in 1836, a great deal has been done in investigating cases in which malformation of the sexual organs has been found. Further, great advance has been made in the study of embryology, and the true interpretation of malformations is more readily arrived at from the embryological standpoint. The consequence is that many cases previously described as true hermaphrodites are now no longer so considered. The cases described before Simpson's day were examined macroscopically only. More recent investigation has shown that organs possessing the relations and appearance of ovaries situated in the broad ligament of a uterus may in reality be testicles. Microscopic investigation has proved this to be the case again and again; and we must therefore make a very careful histological examination before we draw conclusions as to the true character of the sexual glands in malformed individuals. It would appear desirable that we should abandon Simpson's classification, which, in the light of our present knowledge, is not sufficiently clear or comprehensive. Thus Simpson designates by the term 'transverse hermaphrodite' a case in which the uterus masculinus is present,—cases, in fact, similar

¹ Todd's *Cyclopædia of Anatomy and Physiology*, article "Hermaphroditism," Sir J. Y. Simpson, vol. ii. p. 684, 1836-39.

to the one which I describe at the beginning of this paper. Simpson's classification of such cases is based upon the supposition that we have here individuals in whom the external organs are male and the internal organs female. The classification, however, is at once found to be inadequate when we have, as in the case reported, the testicles undescended. Under such conditions they are found to occupy a position in relation to the broad ligament of the uterus similar to that of the ovaries under normal conditions. This was observed in a number of the cases to which I have referred in my paper. The testicles are therefore internal organs in these individuals, and, no doubt, in the earlier cases reported, were looked upon as ovaries, a microscopic examination not having been made.

The classification of Klebs seems to be more satisfactory. The term 'hermaphroditismus verus' is reserved for those cases in which an ovary and a testicle exist in the same individual:—

- (a) Hermaphroditismus verus bilateralis, where an ovary and a testicle exists on each side.
- (b) Hermaphroditismus verus unilateralis, where an ovary and a testicle are on one side and one gland only on the other.
- (c) Hermaphroditismus verus lateralis, where there is a testicle on one side and an ovary on the other.

Klebs includes all other cases of malformation of the character under consideration as 'hermaphroditismus spurius.' Klebs' classification is adopted by Ziegler¹ and by Schultze.² The latter author believes that cases of h. verus bilateralis and of h. verus unilateralis have not been investigated with sufficient accuracy in man. He believes that the two sexual glands are never completely developed as separate organs from the 'geschlechtsleiste' of one side. He, however, states that the cranial end of the 'geschlechtsleiste' in process of development takes on the structure of ovary, the caudal end that of a testicle, forming thus a single structure presenting at one part ovarian and at another part testicular structure. Both of these, however, never become mature, so as to develop ripe ova and spermatozoa. Schultze believes, however, that Klebs' third variety,

¹ Ziegler's *Pathologische Anatomie*, achte Auflage, Band 1, p. 529, 1895.

² *Grundriss der Entwicklungsgeschichte des Menschen und der Säugethiere*, von Dr Oscar Schultze, Leipzig, 1897, p. 448.

viz., *h. verus lateralis*, has been observed in man. An interesting observation of Schultze is to the effect that in certain cases two glandular bodies are found in man on the same side, one of which is undoubtedly developed from the '*geschlechtsleiste*,' whilst the other, in Schultze's opinion, represents an abnormal development of the Wolffian body.

The simplest and the most comprehensive classification is, I believe, that mentioned by Siegenbeek van Heukelom in the paper mentioned above, and which the author ascribes to the French writers. Cases are classified under two headings:— '*Tubular Hermaphroditism*,' where male and female sexual ducts persist in the same individual; and '*Glandular Hermaphroditism*,' where, besides one or two male sexual glands, there are also one or two female glands.

We therefore look upon the case which I have described, in which there was found a well-developed uterus and vagina in the male, as a case of tubular hermaphroditism.

The question as to the possibility of the occurrence of true glandular hermaphroditism in man was thought to have been decided in the affirmative when Simpson published his paper in 1836. Later authorities claimed that a microscopic examination of the sexual glands was necessary, and refused to believe that many of Simpson's recorded cases were true hermaphrodites, as a histological examination had not been made. Some four cases have, however, been investigated under the microscope, viz., cases recorded by Heppner, Schmorl, Obolonsky, and Blacker; these have been admitted to be cases of glandular hermaphroditism.

Siegenbeek van Heukelom, however, challenges all these, believing that the histological characteristics described are not sufficiently conclusive, and states that we have yet no certain proof of the existence of true glandular hermaphroditism in man.

Referring now for one moment to the significance of the conditions found in the case of uterus masculinus which I have described, it is obvious that the fate of the Müllerian ducts is indicated thereby. By studying the early embryo one can trace the Müllerian ducts and the Wolffian ducts, and can observe their relations to the prostate and the neck of the bladder.

Fig. 1.

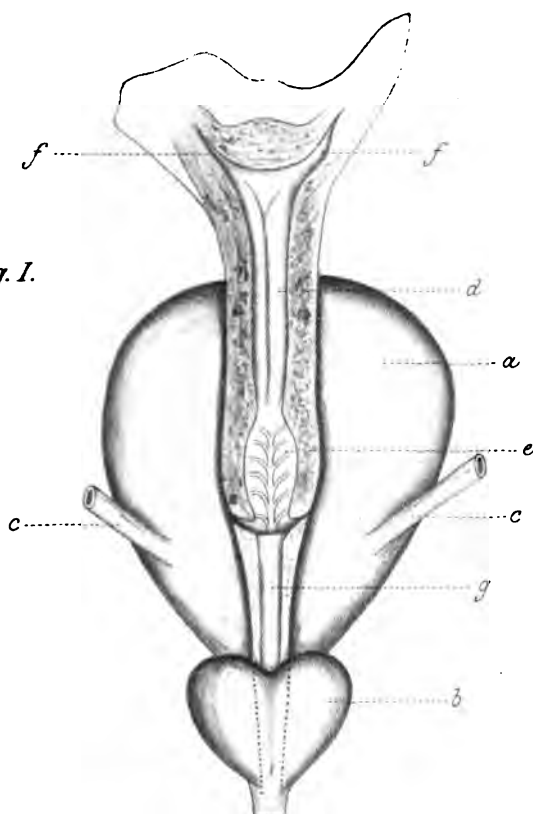


Fig. 2.

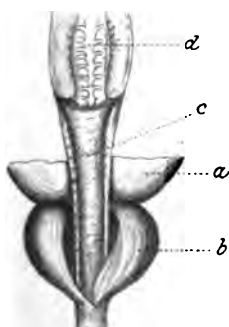
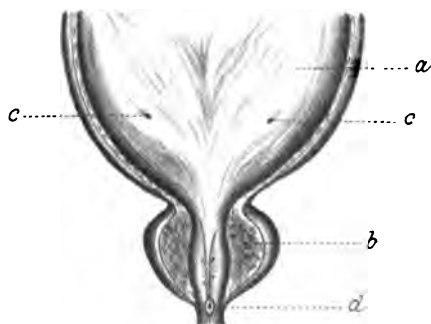


Fig. 3.



Further, it is possible to determine the fate of these ducts from the embryological standpoint alone. These cases of tubular hermaphroditism, however, prove the accuracy of our conclusions. We can affirm with certainty, for example, that the Müllerian ducts develop into the vagina, uterus and fallopian tubes. The series of malformations, the records of which I have collected and referred to in this paper, would lead us to that conclusion. We have examples of unfused Müllerian ducts persisting in the male in the cases recorded by Remy, Martin, and Boogaard. Then we have partially fused Müllerian ducts in the case recorded by Siegenbeek van Heukelom, resulting in a bicornuate uterus occurring in the male. Lastly, we have the normal degree of fusion resulting in the complete uterus and vagina occurring in the male, as in the cases recorded by Langer, Willett, Stonham and myself. In these last-named cases the fallopian tubes were also distinguishable. The characteristic appearances of the mucous membrane were noted in most of these cases; thus, the existence of the uterine glands on the body of the uterus, the plicæ palmatæ in the cervix, and the rugose condition of the mucous membrane of the vagina.

The term 'uterus masculinus,' as applied to the prostatic sinus existing under normal conditions in the male prostate, was evidently used by the earlier anatomists with the conception that it was the homologue of the female uterus; it is, of course, evident that it in reality must be looked upon as the homologue of the series of structures formed in the female by the fused portions of the Müllerian ducts.

EXPLANATION OF PLATE I.

Fig. 1. *a*, bladder; *b*, prostate; *cc*, ureters; *d*, uterus; *e*, cervix uteri; *f*, fallopian tubes; *g*, vagina. Seen from behind.

Fig. 2. View from behind, the prostate *b* being slit up to show *c*, the vagina, continued into it; *d*, cervix uteri; *a*, the neck of the bladder.

Fig. 3. View from the front. *a*, bladder; *b*, prostate; *cc*, openings of ureters; *d*, opening of vagina into floor of prostatic urethra.

A NEW DISSECTION SHOWING THE INTERNAL GROSS
ANATOMY OF THE HIPPOCAMPUS MAJOR. By
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*M'Gill University, Montreal.*¹

By a new method in the dissection of the hippocampus major, I have been able recently to demonstrate some peculiarities in the formation of its central matter in the adult brain, which seem worthy of being placed on record, though some of the details of the work remain yet to be completed.

Some forty brains were examined, of which several proved unsuitable on account of improper preparation. They were previously hardened in a 10 per cent. solution of formalin, with exception of three hardened in alcohol and one in Müller's fluid.

As a rule, about one week in the formalin solution rendered them sufficiently firm to permit of the following dissection:—

The hippocampus major being exposed in its whole extent, an incision is made along its convexity, close to the floor of the descending cornu, penetrating through the alveus and upper strata of grey matter, when, on gently separating the cut portion, a cleavage appears following the convexity of the hippocampus major, as far as the pes. The 'core,' if I may so designate it, of the hippocampus is seen to separate from the more superficial strata of grey substance in the outer wall of the cornu ammonis, presenting along its convexity numerous tooth-like processes, in some cases sharply defined, in others less marked, interdigitating with similar processes in the adjacent grey matter. These tooth-like processes along the convexity of the central grey matter are found to vary considerably as to their number and prominence (fig. 1).

In some brains they are found to increase gradually in size towards the pes hippocampi, in others the processes are better defined at the middle of the hippocampus, being less distinct towards either extremity, and again in some, probably about 6

¹ Read before the British Medical Association in Edinburgh, July 1898.

per cent., of the brains examined they were absent, or at most replaced by a slightly wavy appearance of the surface.

At the pes the processes are different in position and extent. To expose them it is necessary to remove the white and part of



FIG. 1.—The superficial portion of the hippocampus removed and the 'core' exposed, showing the tooth-like processes interdigitating with processes in adjacent grey matter.

the grey substance on its anterior surface, beginning at the line of incision along the convexity of the hippocampus to the extremity of the pes, and dissecting from without inwards. The grey matter in this region separates with difficulty: the dissec-

tion will, however, be facilitated by using a probe, or some blunt instrument, when prominent ridges will be noticed approaching the surface, separated by deep grooves. These are also found to vary in number and extent. In those brains where the pes hippocampi is prominent with a well-notched extremity, one, two, three, or even four well-defined ridges of grey matter can be demonstrated winding over the anterior surface and the edge of the pes in a somewhat spiral manner. In many of the dissections where the extremity of the cornu ammonis is ill defined, these elevations of the central grey matter are absent from the anterior surface, and appear only at the edge of the pes, varying in different specimens as to their size and number. It is interesting to notice that the notched appearance of the pes hippocampi owes its existence to those elevations which have long since won for it its name, from a fancied resemblance to the foot of an animal.

By following the line of cleavage previously described, the inferior surface of this central grey matter of the pes can be separated, though not so freely as along the convexity of the hippocampus, from the subjacent brain substance. It is comparatively smooth, and only exceptionally is it slightly encroached upon by the prolongation of one or two ridges around its free margin.

If the dissection be now extended further, and the white and upper strata of grey matter overlying the hippocampus be detached as far as the fimbrio-dentate sulcus, the 'core' of the internal grey matter of the hippocampus major is exposed, which in those dissections where the crimping along the convexity is well defined, is in appearance not unlike a caterpillar with its legs protruding outwards into the brain substance. This part of the hippocampus has its origin in a narrow band of grey matter in conjunction with the gyrus dentatus, in close proximity to the splenium corporis callosi, increasing in size with the depth of the dentate fissure, to its termination in the expanded extremity of the hippocampus major, the pes hippocampi. It is composed of the superficial layer of the cortex of the hippocampal convolution, prolonged upwards around the dentate fissure as the involuted medullary lamina of the hippocampus major, and blending around this fissure with the gyrus

dentatus, which completes its inner or concave surface. At the pes the central grey matter is formed by the involution of the superficial medullary lamina over the extremity of the dentate fissure, and is continuous with the superficial cortical layer of the hippocampal gyrus and its uncus. As it approaches the uncus forming the anterior part of the central grey matter of the pes, it overlaps the termination of the gyrus dentatus, which is here wedged in at the bottom of the dentate fissure, between the extremity of the uncus and the hippocampal convolution. The tooth-like processes exposed on the convexity of the internal grey matter, as well as the spiral ridges on the superior surface and edge of the pes, are formed by the crimping of the involuted medullary lamina.

The relation of the dentate convolution to this internal pleating in the grey substance of the hippocampus major is shown on carefully separating the lips of the dentate fissure. In many of the specimens, processes coinciding with the elevations in the interior of the hippocampus are noticed on the outer surface of the dentate gyrus, but they are usually fewer in number, not as well defined, neither are they as prominent, whilst in others the internal dissection of the hippocampus shows a visible crimping, when the gyrus dentatus in the dentate fissure is free from any corresponding processes. It follows that the tooth-like processes of the dentate gyrus, when present, will be found to coincide with similar elevations in the central grey matter of the cornu ammonis; and secondly, that absence of dentate processes in the dentate fissure does not necessarily indicate absence of the crimping within the hippocampus; on the contrary, in a few of the brains examined, these were found to exist, notwithstanding a comparatively smooth dentate fissure.

In order to define the line of cleavage in the grey matter, vertical sections are made through the hippocampus major and hippocampal convolution, and by means of a pocket lens, or even the naked eye, the line of separation can be seen, which on slight pressure can be made to open widely. This cleavage is always seen at the same level, and the separated surfaces present a smooth appearance. Though the few microscopical examinations of the sections made do not justify a positive assertion, yet I am inclined, until further investigation, to look upon the

cleavage as probably an artificial separation between the involuted medullary lamina and the more superficial strata of grey matter of the hippocampus major.

The causes of this crimping in the internal grey matter of the hippocampus major can well be attributed to the amount of

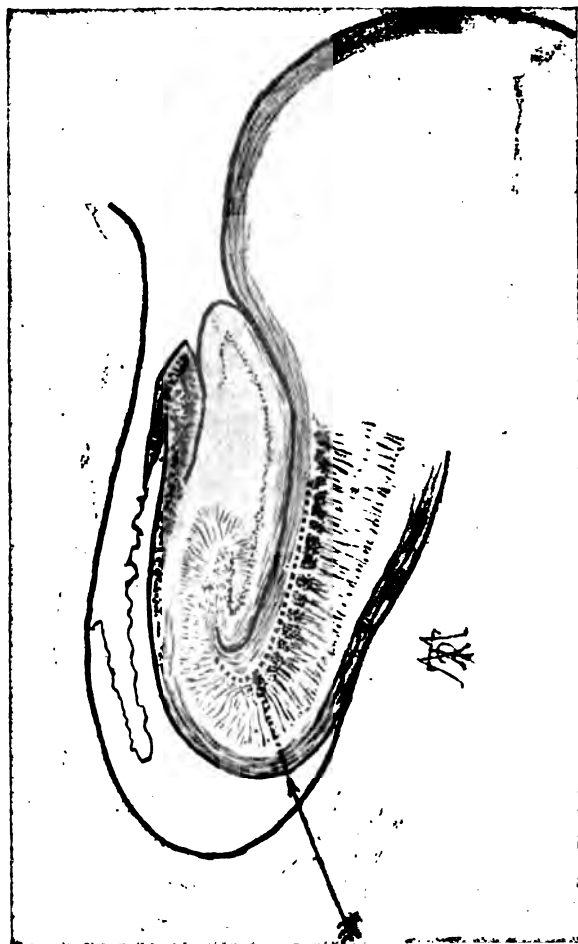


FIG. 2.—Vertical section through the hippocampus major. The arrow points to the line of cleavage.

pressure to which this region is subjected during the period of development, the soft and yielding brain matter being pushed out where there is the least resistance. The inner or concave surface of the grey matter retains a smooth appearance,

most likely from the resistance offered by the greater density of the optic thalamus and crus cerebri.

The spiral outline of the ridges of the pes indicate a slight outward rotation of the extremity of the hippocampus on its axis, which the direction of the dentate fissure would tend to confirm: indenting the cortex in the first part of its course outwards and upwards, it gradually becomes horizontal as we approach its termination between the hippocampal gyrus and its uncus, indicating this outward twisting of the pes hippocampi in the process of development, which gives rise to the wavy outline that the ridges assume on the anterior surface of the pes, as shown in the dissections.

No fetal brains have been examined, owing to the scarcity of material; whilst two infants' brains only were obtained under three months, which unfortunately were not sufficiently firm to permit of a successful dissection. As far as could be seen, there was no visible crimping of the internal grey matter. It is possible that they make their appearance later on in life, which subsequent examinations will determine, as well as their presence or absence in the brain of the lower animals.

I feel much indebted to my teacher, Dr F. J. Shepherd, Professor of Anatomy, M'Gill University, Montreal, for his valuable review of my work; and to my colleague, Dr R. Tait M'Kenzie, Demonstrator of Anatomy, M'Gill University, Montreal, for the pains he has taken in the careful drawings he has made from the dissections.

This structure may be appropriately called the "*corrugated core of the hippocampus*."

NOTE ON A FÆTUS OF *GORILLA SAVAGEI*. By
W. L. H. DUCKWORTH, M.A., Fellow of Jesus College, Cam-
bridge.

THE specimen under consideration (fig. 1) appears to be the smallest representative of its species hitherto described. It was presented (with the skeleton of an adult female gorilla) to the Museum of Comparative Anatomy in the University by Capt.



FIG. 1.

Hopkins (H.M. Consul at Loanda) in the year 1876. It is, unfortunately, not quite uninjured, for the outer aspect of the left upper limb is lacerated, and the right foot is imperfect, and only attached to the leg by a few tendons and ligamentous bands. The preservative is alcohol. The sex of the specimen is only just recognisable from the conformation of the external genitalia, which indicate a male. The principal dimensions of the trunk, head, and limbs are recorded in the subjoined table. One may mention here that the length from vertex to coccyx is 71 mm.

From the descriptive point of view, the following notes have been made out:—

The head is relatively large, globular, and a nuchal depression is conspicuous by its absence. The eyes are large and protruding, but the eyelids are closed. The nose has no bridge, and so resembles the adult organ, but its lower part seems to project rather more than in older specimens. The ears are somewhat distorted and injured from pressure; an indication of inrolling of the helix appears on the right side; some of the tubercles still stand out imperfectly fused (especially the antitragus). A puncture in front of the left auricle suggests imperfect closure of a branchial cleft. The mouth is characteristically large, the upper lip being 'shallow,' and so differing from that of chimpanzee.

In colour the skin is uniformly whitish or grayish, no indication of the black pigmentation of older specimens being as yet apparent. The whole body is hairless, no 'lanugo' being perceptible. The upper limbs are slender, the hands being wide and long, with stout fingers and a short pollex (see figs. 2 and 3 (c and d)). The lower limbs are proportionately short, the joints are strongly flexed, and the foot distinctly pithecoïd, *i.e.*, with short, outstanding hallux, and prominent halluceal musculature. Cutaneous 'grooves' are seen both on plantar and on palmar surfaces; and it is noteworthy, in view of the observations of Hepburn¹ on this point, that transverse grooves are quite inconsiderable in comparison with those of the longitudinal and oblique groups (see fig. 3, c and d).

The spinal column is bent into a convexity directed uniformly backwards; at the lower end of the column the coccyx is visible through the skin, appearing as several bluish and shining cartilaginous plates, about 3 mm. posterior to the anus.

The abdomen is full and rounded; the umbilicus situate near the pubes. The external genitalia are represented by an almost sessile penis, a trace of the glans being just distinguishable; the organ is still grooved along its lower surface. Testes are impalpable.

The above description has been supplemented by a comparison of this fœtus with two human specimens in the Anatomical

¹ Published in *this Journal*, 1892.

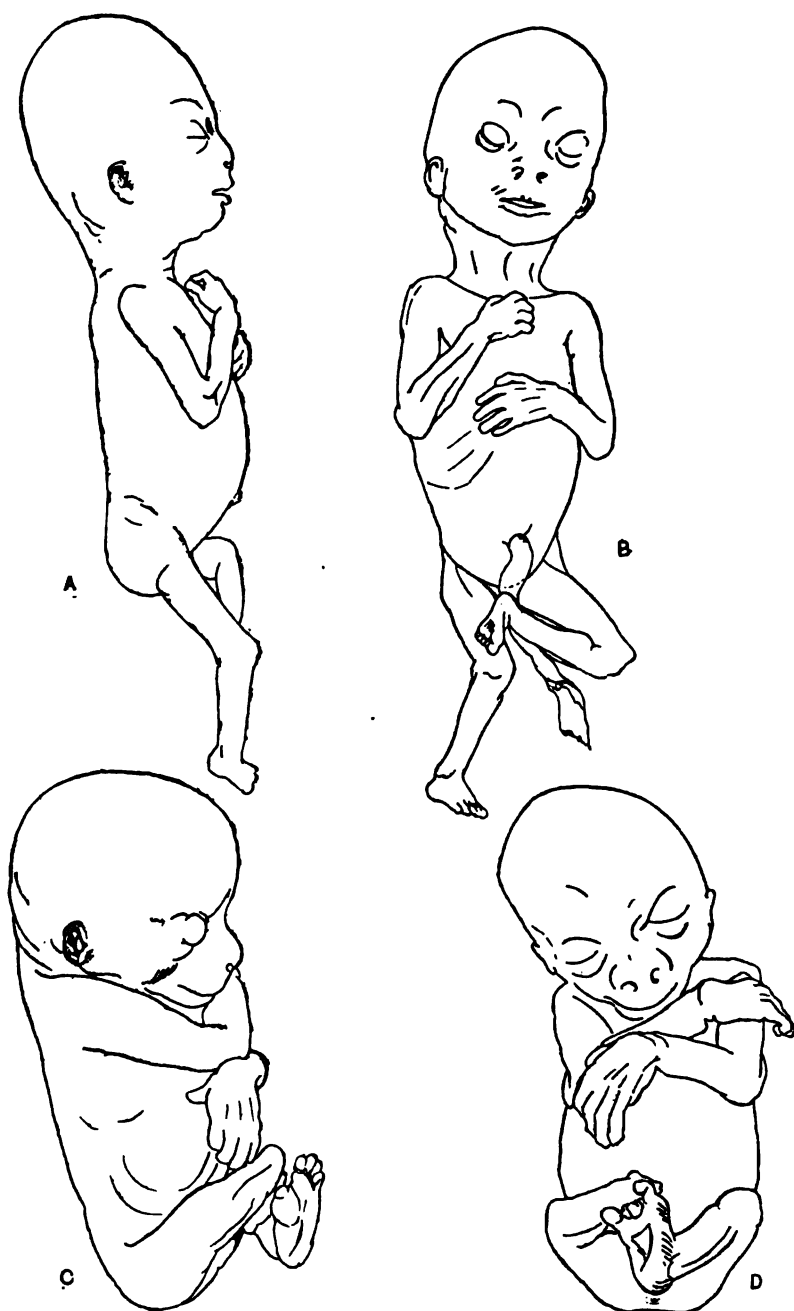


FIG. 2.

A and B, outline drawings of a human fetus (said to be $4\frac{1}{2}$ months old), from photographs, and of the actual size of the specimen.

C and D, similar drawings (of actual size) of fetus of gorilla.

Museum, which nearly approach the gorilla specimen in size. Their weights, though recorded, were discarded as a basis of comparison. The two human specimens were characterised as follows:—The first is represented in fig. 2, A and B, of this paper, and is the same as (3) of the *Table (q.r.)*, viz, a human fœtus of 107.5 mm. extreme height, and 76 mm. from vertex to coccyx. It is stated to be of the age of $4\frac{1}{2}$ months. The other human fœtus, No. 29 of the Lee Collection in the Anatomical Museum, measures much less (66 mm.) from vertex to coccyx, and was chiefly used in order to show that even at its age, which is stated to be 4 months, the human characteristics of hand and foot are clearly marked in the fœtus. The hand and foot of this specimen are therefore figured in fig. 6. A comparison of the external forms of these human fœtuses with that of the gorilla fœtus leads to the following remarks:—

The size of the head in gorilla appears, proportionately to the total bulk, greater than in man, in whom there is a marked nuchal depression, which, as remarked above, is not visible in gorilla.

The ears in all these specimens appear to have attained about the same stage of development. A furrow, limiting the helix on its proximal side, is rather more distinct in the human fœtus, and gives a more marked indication of inrolling of the pinna.

The eyes are large and bulging in both cases, gorilla and man alike.

The facial components of the head in man are distinctly smaller, absolutely and proportionately, than in the gorilla fœtus; the jaws in man are less prominent (less prognathous), the nostrils smaller and proportionately rather farther apart, the rictus oris is distinctly smaller than in gorilla: some of these facts are indicated by the respective dimensions of the parts. (See Table of Measurements.)

The neck in man is, even at this stage, more slender, and therefore more distinct than in gorilla.

The trunk in the gorilla is stouter than in man; the iliac bones seem to have already acquired the features which are so characteristic of these bones in adult examples. The navel is situated low down on the abdominal wall in both cases.

The upper extremities in man are more slender, absolutely and

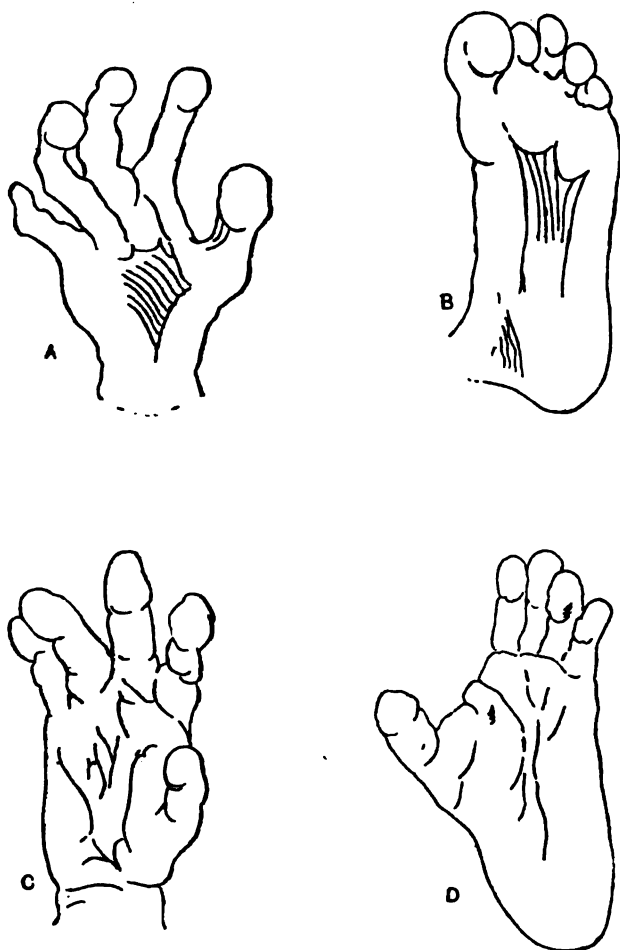


FIG. 3.

A and B, outline drawings from photographs of palmar and plantar surfaces of the extremities of a human fetus (No. 29 of the Lee Collection), said to be 4 months old.

C and D, corresponding palmar (C) and plantar (D) surfaces of the extremities of the fetal gorilla which is here described.

All these are enlarged from photographs of the original parts. Thus C, with an original length of 13 mm., has been enlarged $3\frac{1}{2}$ times, and D (original length 15 mm.) has been enlarged $3\frac{3}{8}$ times. A and B were originally of smaller size than C and D respectively, but have been enlarged to similar dimensions for the sake of comparison.

proportionately, and the forearm and manus contribute much less to the length of the limb than they do in gorilla; the pollex in man already reaches to the distal end of the first phalanx of the index digit; in gorilla the pollex is far shorter, barely surpassing the distal end of the metacarpal bone of the second digit.

The lower extremities in man are more slender, and there is greater apparent inward torsion of the thigh. The whole limb is relatively longer in man, the ankle more slim, the plantar surface of the foot less inverted than in gorilla. The human foot has already (see fig. 3, A and B) attained to its characteristic conformation, and even in this younger and smaller human foetus a few grooves are visible. These may, however, be merely due to contraction, owing to the effect of the preservative. Grooves are distinct on the plantar surface in gorilla; the appearance of the pes in the latter has already been described.

Turning now from the comparisons based on the material at Cambridge exclusively, one must, in the first place, refer to Deniker's monograph on the foetal gorilla.¹ This is the only description of a foetal gorilla that I have been able to refer to; the specimen dealt with therein was much larger than the subject of this communication, being about 196 mm. in total length, i.e., more than twice the length of the Cambridge specimen. In the accompanying Table of Measurements, I have recorded the dimensions of the Cambridge specimen side by side with those published by Deniker of his gorilla, and I have added similar measurements of a human foetus reputed to be at the eighteenth week (4½ months).

A brief survey of the table will show the close approximation in actual dimensions of head and trunk of the (Cambridge) gorilla foetus and human foetus, Deniker's specimen being much larger than either. A word of warning must be given here as to the difficulty of accurate measurements of the dimensions of such foetal specimens.

In the latter part of the table certain proportions are given. It is interesting to notice in the Cambridge specimen (*a*) the smaller contribution to the total height made by the limbs; this one would expect in an earlier stage than Deniker's speci-

¹ Published in *Archives de Zoologie Expérimentale et Générale*, 2^e série, tome iii. bis, supplémentaire, 1885.

men: (b) in the Cambridge specimen, the upper extremity is of much greater length in comparison with the lower than is the case with Deniker's specimen; this, again, is what one would expect in the younger animal.

As regards arm and forearm, the proportions are sub-equal in both the Cambridge and Deniker's specimens (dolicho-kerkic); but as regards thigh and leg, the figures (thigh=100; leg in Deniker's specimen=67.3; in Cambridge specimen=76.4) show that the leg is very long in the earlier stage, and that subsequent growth, as far as the stage of Deniker's specimen, is chiefly 'thigh-growth,' after which, again, 'leg-growth' predominates, as is shown by the index being greater than 83 in adult gorilla (see Turner, *Challenger Reports*, "Bones of the Skeleton").

Lastly, as regards thigh and arm, the greater length of arm in comparison with thigh found in the Cambridge specimen is probably a reiteration of the indication given by excess of upper limb over lower limb taken in totality, and depends on the lesser age of the specimen; it is also influenced by the comparatively dolicho-knemic character just referred to of the Cambridge specimen (n.b. *comparatively* dolicho-knemic, for its index, 76.4, does not place it in Turner's dolicho-knemic class, for which, in fact, the index must be greater than 83).

Turning now to comparisons between the gorilla foetus and human foetus of approximately identical bulk and length. The stature being taken as =100, the human foetus shows a human character in that the trunk forms a much smaller portion of this total than it does in gorilla, and the lower limbs accordingly form a greater proportion than in gorilla: this last fact is not, however, brought out by the figures for the lower limbs, owing to the difficulty in making certain of *points de repère*. Inasmuch, however, as the first set of dimensions, viz., total length, and length from vertex to coccyx, are more easily ascertained than limb-length, greater importance should be attached to indications afforded by the former. Secondly, the proportionate shortness of the upper extremity has already appeared in man (32 p.c. pro 45 p.c. of stature), and herein the elder gorilla foetus (Deniker's) with 50 p.c. has still further departed from the human figure than has the younger specimen. It would be more just, however, to compare Deniker's figures with those relating to a

human foetus of age corresponding to that of DeMeillon's specimen. The shortness of the human forearm and manus in comparison with upper arm is already distinct, as is manifested by the figures (*q.r.*), and so is the excess of lower limb over upper limb. On the other hand, in comparison of thigh with arm, the human foetus is intermediate between the gorilla fetus and adult man.

To sum up, the general trend of evidence is to indicate that in considering the ontogeny of man in comparison with that of gorilla (and probably of other anthropoid apes) the distinctive characters are quite plainly manifested at even early stages in foetal life; and this is an indication of the importance to be attached to such differences as are thus early shown.

From this consideration one is confirmed in the belief that in their phylogenetic history, the stock of the anthropoid apes as we know them at the present time, diverged from the precursors of man at a correspondingly early stage. As such a consideration is not without importance in influencing one's views on transitional types between man and apes, this discussion of the facts presented by the recorded figures has been appended to the actual description of the foetal gorilla which forms the subject of this communication.

EXPLANATION OF FIGURES.

Fig. 1. Profile view of foetal gorilla.

Fig. 2. Outline drawings of human foetus of 4½ months and 76 mm. (A and B), for comparison with foetus of gorilla (C and D).

Fig. 3. Outline drawings of palmar and plantar aspects of extremities of a human foetus of 4 months (66 mm.), and of gorilla foetus (71 mm.).

The drawings in figs. 2 and 3 are from photographs.

Comparative Table of Measurements.

Column 1. Deniker's data. Specimen. Sex ♀.

" 2. Gorilla fetus in Cambridge Zoological Museum. Sex ♂.

" 3. Human fetus in Cambridge Anatomical School. Sex ♂.

DIMENSION.	1.	2.	3.	
Vertex to plantar surface, . . .	196	188	107.5	
Vertex to coccyx, . . .	135	71	176	
7th cerv. vert. to coccyx, . . .	91	145	145	
Head—Max. antero-posterior diam., . . .	58	129	26.5	
Max. transverse diam., . . .	48	124	23.5	
Vertex to chin, . . .	60	82	31	
Bzygomatic diam., . . .	49	122	18.5	
Interocular, internal, . . .	12	6	6	
external, . . .	34	18	17	
Nose—Height, . . .	20	8	5.5	
Width, . . .	19	7.5	5	
Ear—Height, . . .	16	6	5	
Width, . . .	10	3.5	3	
Width of rictus oris, . . .	26	10 (14)	5.5	
Horizontal oce. of head, . . .	173	88	83	
Trunk—Deltoid width, . . .	72	27.5	25.5	
Width between axillæ, . . .	61	18	18	
mammillæ, . . .	32	11	12	
Horizontal oce. of thorax, . . .	166	173	65	
Presternal notch to pubis, . . .	54	33	35	
Umbilicus to " . . .	24	6	7	
Iliac (intercostal) breadth, . . .	47	120	19	
Upper extremity—Arm, . . .	53	21R	19	
Forearm, . . .	47	19R	15.5	
Manus to tip of medius, . . .	38	13R	11	
Palm, . . .	19.5	7R	5.5	
Pollex, . . .	11	2.5R	4	
Index, . . .	16.5	3.5	4.5	
Medius, . . .	17.5	4.5	5	
Annularis, . . .	15	4.5	4.5	
Total length, upper limb, . . .	133	53	45.5	
Lower extremity—Thigh, . . .	49	17	19	
Leg, . . .	33	13	16	
Pes, length, . . .	44	15	10	
breadth, . . .	13	7	4	
Hallux, . . .	11.5	2.5	2	
2nd digit, . . .	8.5	2.5	12.5	
3rd digit . . .	10	..	..
Trochanter to heel, . . .	..	34	34	
(Hallux)—Base of digit 1—digit 2, . . .	9	2.5	..	
Total length of lower extremity, less pes, . . .	32	30	35	
Stature = 100—Vertex to coccyx, . . .	69	80.7	70.7	
Biacromial breadth, . . .	23	81.2	23.7	
Upper extremity, . . .	70	60.2	42.2	
" les manus, . . .	51	45.4	32.1	
Arm, . . .	27	23.5	17.7	
Forearm, . . .	24	21.6	14.4	
Manus, . . .	19	14.8	10.2	
Lower extremity, less pes, . . .	42	34.9	32.5	
Trochanter to calc., . . .	53	138.7	31.6	
Pes, . . .	23	17	9.3	
Cephalic height, . . .	30.5	136.3	28.8	
Trunk = 100—Upper extremity, . . .	101.9	74.6	45.4	
Lower extremity, less pes, . . .	43.8	42.2	46	
Trochanter to heel, . . .	..	147.8	44.7	
Arm = 100—Forearm, . . .	88.8	90.4	81.6	
Manus, . . .	71.5	61.9	57.9	
Upper limb = 100—Lower limb, . . .	142.4	175	98.8	
Lower limb = 100—Upper limb, . . .	121.9	133.3	98.6	Adult gorilla, 118. Adult European, 69.5.
Thigh = 100—Arm, . . .	108.1	123.5	100	Adult gorilla, 119. Adult European, 72.5.
Thigh = 100—Leg, . . .	67.3	76.4	84.2	Adult gorilla, 83+. Adult European, 83+.
Weight, . . .	..	31	26	

**THE ACTION OF CERTAIN DRUGS AND MINERAL-
WATERS ON THE SECRETION AND COMPOSI-
TION OF HUMAN BILE: AN EXPERIMENTAL INVE-
STIGATION.¹ By WILLIAM BAIN, M.D. Durh., M.R.C.P. Lond.**

THE investigation of cholagogues is one of the most difficult in the whole domain of pharmacology. The importance of the subject is shown by the number of laborious researches undertaken to determine the action of drugs which are supposed to influence the secretion of bile, and its complexity by the contradictory results obtained. As nearly all recent experimental evidence casts doubt on the existence of so-called cholagogues, it occurred to me that the time would be well spent if I could contribute, even in a minor degree, towards a solution of this very difficult problem. While arrangements were being completed for carrying out a series of investigations on dogs by means of Schiff's amphibolic biliary fistula in the Physiological Laboratory of St Thomas's Hospital, I was informed that a patient with a permanent cutaneous biliary fistula had just left the institution. An interview was immediately arranged with this man, who readily consented to place himself at my disposal for experimental purposes. In mentioning the history of the patient, I wish to acknowledge Dr Payne's kindness in permitting a reference to the notes of the case.

The patient, male, aged 49, was admitted into St Thomas's Hospital, under the care of Dr Payne, on July 19th, 1897, and was operated upon by Mr Anderson on the 29th of the same month. At the operation the gall-bladder was found tensely distended, and contained clear fluid. The cause of the obstruction in the common bile-duct was not ascertained, though a careful search was made. The opinion expressed at the time was that it was probably due to a small impacted gall-stone. As the patient seven months later was in a satisfactory state of health, this view is probably correct. He was discharged from the hospital on October 20th. During his stay there his stools

¹ From the Physiological Laboratory of St Thomas's Hospital.

were always clay-coloured. His weight on admission was 9 st. ; on his discharge, 8 st. 9 lb.

When he came under my notice on the 7th of November his health was moderately good. He was anæmic, and troubled more or less with flatulence, but no organic disease could be detected. His appetite was good, and he took a moderate amount of exercise. He lodged close to the hospital, and brought the bile and urine each day to the laboratory. His height was 5 ft. 1 in., and his weight on November 11th, without clothes, 58 kilogrammes (9 st. 2 lb.). He only varied 2 lb. while under my observation, and during the latter part of the period he "felt much better and stronger." His bowels were moved naturally once a day after leaving the hospital, but this action was subsequently modified by the drugs taken. His diet was as follows:—

At 9—Breakfast—Egg, lean bacon, tea and bread.

At 11—Luncheon—One pint of porter.

At 1.30—Dinner—Mutton or beef, potatoes and bread. Occasionally he had fish. Water.

5.30—Tea, bread and butter.

I asked him to take the same amount of food, liquid, and exercise each day, and impressed upon him the necessity for abiding by these rules, as otherwise my results would be vitiated. In addition, he took 36 grains of purified ox-bile daily (12 grains at 10 A.M. and at 2 and 6 P.M.), thus approximating the experimental conditions to the normal standard.

Method of collecting the Bile.—Arbuthnot Lane's biliary tube was employed, which answered the purpose admirably. By means of sticking-plaster the shield was kept in absolute contact with the skin, so that not a drop of bile was lost. The inner was fastened to the outer tube with a small safety-pin to prevent traction. The outer end of the collecting-tube was firmly attached to an india-rubber urinal, fitted with a stop-cock. This allowed the patient to collect the bile at stated times without in any way disturbing the connections. The tube was changed about once a week. During the seventy days the case was under observation, only on two occasions was there any oozing, due to an insufficiency of plaster.

The bile was collected four times a day—at 8 A.M., at 12

noon, at 4 P.M., and at 8 P.M.—and put into different sized bottles, properly labelled. The specific gravity of each sample was taken at the laboratory temperature, and the same hydrometer was used throughout. Then the four specimens were put into one bottle, shaken, and a portion reserved for analysis.

METHOD OF ANALYSIS.

Bile Solids.—The weight of the capsule was first ascertained, 25 c.c. of bile measured (the same pipette was always used for this and for estimating the bile salts) and weighed, then evaporated to dryness over a water-bath at a temperature of 100° C. The capsule was next placed in a hot air chamber kept at a temperature of 110° C. by means of a gas regulating apparatus for at least three hours. After that it was placed in an exsiccator until its weight was constant.

Bile Salts.—To 25 c.c. of bile about 120 c.c. of methylated spirit was added, and the whole filtered. The filtrate and washings were evaporated to dryness over a water-bath, and extracted with absolute alcohol. The extract was then evaporated to a small volume, and two-thirds of its volume of anhydrous ether added. This was allowed to stand in a cool place for three days, and the precipitate of bile salts was then collected on a weighed filter. The filtrate was again evaporated to dryness, extracted and precipitated as before, and any further precipitate collected on the same filter. The filter was finally dried at 105 C. to constant weight.

I take this opportunity of expressing my gratitude to Dr Brodie for his advice, and for many acts of kindness. I also have to thank Dr Sikes, Demonstrator of Physiology, for analysing the bile and urine on two occasions during my absence.

For the purpose of comparing results, I will briefly mention the salient facts in the published cases of human biliary fistula.

Monro mentions a case of abscess of the liver where the bile was discharged by coughing, mixed with mucus and saliva. The quantity varied from 10 to 15 oz. in the twenty-four hours. It was irregular in flow, and greater in quantity after dinner.

Charles Robin (2) mentions a case of Taconi's where a patient

had a biliary fistula. The bile amounted to 500 grammes in the twenty-four hours.

Harley (3) describes a case of hydatids of the liver where the bile was discharged through a fistulous opening, the quantity varying from 16 to 20 oz.

Murchison (4) records a case of biliary fistula where the bile flowed at the rate of 1 to 2 oz. per hour, usually increasing after meals.

Frerichs (5) quotes a case of Rouis' where 900 grammes of bile a day was expectorated.

Ranke (6) records a case of hydatid disease of the liver where a communication existed between the bile-passages and a bronchus. Sometimes the bile was expectorated, while at others it passed into the duodenum. He gives the results of five observations of twenty-four hours' duration, when the fæces gave no indication of biliary constituents. The patient had chronic bronchitis, and allowance had to be made for the secretion from the respiratory passages. The average of these observations gives 636 c.c. of bile, with 20.6 grammes solid.

Noel (7) mentions a case of biliary fistula. On one occasion 900 grammes of bile were secreted in the twenty-four hours, with a specific gravity of 1.0097.

Von Wittich (8) has published a case where a biliary fistula formed spontaneously on account of an impacted gall-stone. He collected the bile for four hours during the day and for ten hours during the night, and from these data he calculated the amount in the twenty-four hours.

Westphalen (9) describes a case of liver abscess where the bile found its way into the right pleura, and subsequently, after thoracocentesis, through the thoracic wall. Taking the average of seventeen days, the bile amounted to 498 grammes, with 11.268 grammes solid. The bile was analysed by Jacobsen. Westphalen tried the effects of water, calomel, and quinine on the biliary secretion. He found that large quantities of water did not increase the secretion, nor alter the composition of bile. Calomel and quinine had no effect.

Yeo and Herroun (10) made a number of observations on a case of fistula due to cancer of the common duct. The patient was very ill at the time, and took little nourishment. The average

quantity of bile secreted during the 24 hours only amounted to 374 c.c., with 5.044 grammes solids. No difference in the rate of secretion was noticed after the small meals taken by the patient.

Hammersten (11) records seven cases of biliary fistula, but in all of them a part of the bile found its way into the intestine. The percentage of solids in his cases varied from 1.63 to 3.53 per cent.

Edington (12) published a case of biliary fistula, but the obstruction was incomplete, so that some of the bile escaped into the duodenum.

The next four cases are important, as the patients, apart from the fistula, were in good health at the time of observation, and the obstruction was complete.

Copeman and Winston (13) record a case of biliary fistula in which the average amount of bile secreted in the 24 hours was 779 c.c., with 11.094 grammes solids. They endeavoured to determine the variations in the flow of bile in relation to time and meals.

Mayo Robson (14) reports some interesting observations which he made on a case of biliary fistula. The quantity of bile collected on various dates during the time the patient was in hospital averaged 850 c.c. Mr Fairley analysed the bile on two occasions: the mean gives 15.28 grammes solids. Mr Robson investigated the action of the following drugs:—calomel, rhubarb, podophyllin, carbonate of soda, iridin, euonymin, turpentine, and benzoate of soda. Unfortunately, Mr Robson did not analyse the bile while these experiments were being carried out; he only gives the total quantities collected. He found that iridin increased the flow temporarily, while aerated soda-water had the same effect, without a subsequent fall. The other drugs had no effect.

Noel Paton and Balfour (15) describe a case of biliary fistula where they made a number of careful observations. They experimented with salicylate of soda, calomel, and ox-bile, but at the time the patient was suffering from a moderately high temperature, so that little importance can be attached to their results. They found that salicylate of soda increased both the quantity and the solids; and that although ox-bile and calomel

influenced the secretion, they were less active than the soda salt. A year later, when the patient's health was re-established, Paton (16) had the opportunity of analysing her bile on two successive days. The mean of these observations gave 590 c.c. of bile, with 13·6 grammes solids.

The last recorded case is by Pfaff and Balch (17). Their observations extended over 97 days, and were of a painstaking character. The average of three days without drugs gives 514 c.c., with 8·57 grammes solids. They tried on their patient calomel, corrosive sublimate, salol, ox-bile, human bile, and bile salts. Calomel and corrosive sublimate had no effect; if anything, the quantity was diminished, whereas the percentage of solids did not vary from normal. Salol had some influence, but not pronounced enough to justify them in asserting that it was a cholagogue. Human bile, ox-bile, and bile salts increased both the quantity and the solids.

The amount of Secretion in twenty-four hours.—In taking the average of the daily amount of bile, I excluded those days during which drugs were used, and also the day subsequent to the administration of any drug. Thus the average of sixteen days gave 775 c.c. of bile; the average of nine days 15·893 grammes solids; and the average of 6 days 4·197 grammes bile salts. To save repetition, I may state that when the term *without medication* is used, it refers to these sixteen days. The specific gravity varied during the period without medication from 1·0079 to 1·012. A glance at Table I. will reveal the fact that the quantity of bile in my case is very similar to that of Copeman's and Winston's, but in mine the total solids are much higher. This I attribute to my patient taking ox-bile daily, and also a fair amount of exercise in the open air, while theirs was confined to the wards of an hospital.

TABLE I.—(modified from Ganges (18)).—*Exhibiting the Results of different Observers on the Secretion of Bile and Bile Solids (during 24 hours) in the human subject.*

	Ranke.	Von Wittich.	Westphalen.	Yeo and Herroun.	Copeman and Winston.	Mayo Robson.	Paton.	Pfaff and Balch.	Bain.
Sex.	M.	F.	M.	M.	F.	F.	F.	F.	M.
Weight in kilogrammes,	47	..	...	...	43.7	53	73	51	58
Bile secreted, in c.c.,	636	532	498	374.5	779	819	590	514	775
Bile Solids, in grammes,	20.6	...	11.27	5.04	11.09	15.28	13.596	8.57	15.893
Bile secreted per kilo of body,	13.52 c.c.	...	...	...	17.8 c.c.	16.0 c.c.	8.08 c.c.	10.27 c.c.	13.86 c.c.
Bile Solids secreted per kilo of body,	0.44 grms.	...	...	...	0.25 grms.	0.28 grms.	0.186 grms.	0.168 grms.	0.274 grms.

During the period without medication the smallest quantity of bile was secreted on January 20th, 670 c.c., the largest amount on November 11th, 864 c.c.; similarly, the smallest quantity of solids was secreted on January 24th, 15·139 grammes, whilst the largest was on January 11th, 16·640 grammes.

Variations in the rate of Secretion.—There is abundant proof that the rate of secretion is very irregular, but the conditions which operate to produce this irregularity in flow are, to a certain extent, conjectural. The two most potent factors are probably diet and exercise. It is generally admitted that during digestion the secretion of bile is active, but there is a lack of experimental evidence regarding the kind of diet which most influences the secretion. It appears probable that exercise augments the biliary secretion; but if the exercise produces much perspiration, this effect will be annulled. The evidence I have to adduce in support of this statement is exceedingly meagre. On two occasions when the patient was not having drugs, circumstances arose which compelled him to take more than usual exercise. In these two instances the quantity of bile was increased. An average of the days without medication gives the following quantities:—

From 8 to 12 p.m.,	147·7 c.c.
„ 12 to 4 p.m.,	165·1 c.c.
„ 4 to 8 p.m.,	148 c.c.
„ 8 to 8 a.m.,	312·6 c.c.

It will be observed there is a rise from 12 to 4, which coincides with the principal meal of the day; and the quantity secreted during the day, 471 c.c., is much larger than that during the night, 312 c.c.

The colour of the bile was always of an olive green, the only variation observed being in depth of tint.

The bile was invariably alkaline in reaction.

Pressure of Bile Secretion.—Only one observation was made, on December 14th, at 3.45 p.m., when the pressure was found to be equal to 16 mm. of mercury. This is much less than the mean of Paton's and Balfour's observations, 24 mm. of mercury.

Dr Samuel Fenwick (19) has made numerous observations upon the amount of sulphocyanate of potash in the saliva, in both health and disease. He noticed a marked decrease in the amount when the activity of the nutritional functions was diminished, and in serious febrile affections he regards an increase as an element of favourable prognostic significance. He expresses his belief that the sulphocyanate salt is derived from the biliary salts after they enter the duodenum; and he bases this opinion on the statement that when the bile is prevented from reaching the alimentary canal, as he says happens in one form of dyspepsia characterised by eructations of sulphuretted hydrogen gas, he found the sulphocyanate salt invariably absent from the saliva. If Dr Fenwick's hypothesis be correct, the salt must be absent from the saliva when the common bile-duct is occluded. In order to test this point, the patient was asked to discontinue the ox-bile pills during the Christmas holidays. His saliva was then examined on several occasions, and the sulphocyanate salt was always present, although the quantity was diminished. His saliva was also examined while he was taking ox-bile, but no difference in the reaction could be detected.

In Table II. will be found all particulars relating to the quantity, specific gravity, and analysis both of the bile and urine collected during the 70 days the patient was under my observation.

[TABLE II.

TABLE II.—*Exhibiting the Daily Quantity, Specific Gravity, and Analytical Details of the Bile and Urine.*

Date.	Drug.	Hours.	BILE in 24 hours.					
			Quantity in c.cms.	Specific Gravity.	Solids.		Bile Salts.	
					Total in Grammes.	Per cent.	Total in Grammes.	Per cent.
1897. Nov- ember 11th	...	8.12 pm	197	1009
		12.4 pm	176	1008				
		4.8 pm	104	10095				
		8.8 am	387	1009				
			864	1.0088				
13th	20 oz. Old Sulphur Well, Harrogate, taken warm at 8 am	8.12 pm	195	1008
		12.4 pm	224	1010				
		4.8 pm	142	1008				
		8.8 am	383	1009				
			944	1.009				
14th	...	8.12 pm.	187	1009				
		12.4 pm	203	1009				
		4.8 pm	106	1010				
		8.8 am	316	1007				
			812	1.008				
15th	...	8.12 pm	166	1009				
		12.4 pm	173	1009				
		4.8 pm	148	1008				
		8.8 am	360	1008				
			847	1.0083				
16th	Euonymin, 4 grains, taken at 8.30 am	8.12 pm	163	1008				
		12.4 pm	183	1011				
		4.8 pm	143	1007				
		8.8 am	355	10095				
			844	1.0089				
17th	...	8.12 pm	154	1011				
		12.4 pm	167	1011				
		4.8 pm	114	1008				
		8.8 am	275	1009				
			710	1.0097				
18th	Iridin, 4 grains, taken at 8.30 am	8.12 pm	157	1010				
		12.4 pm	190	1010				
		4.8 pm	121	1007				
		8.8 am	312	1009				
			780	1.0091				

[illegible]

Date.	Drug.	Hours.	BILE in 24 hours.					
			Quantity in c.cms.	Specific Gravity.	Solids.		Bile Salts.	
					Total in Grammes.	Per cent.	Total in Grammes.	Per cent.
1897. Nov- ember 19th	...	8.12 pm 12.4 pm 4.8 pm 8.8 am	148 153 131 325	1008 1009 1007 1008				
			757	1.0081				
20th	...	8.12 pm 12.4 pm 4.8 pm 8.8 am	144 165 124 285	1009 1012 10095 1010				
			713	1.010				
23rd	...	8.12 pm 12.4 pm 4.8 pm 8.8 am	147 183 143 312	1008 10085 10085 1009	...	...	...	...
			785	1.0086	...	...	3.760	.48
24th	...	8.12 pm 12.4 pm 4.8 pm 8.8 am	148 162 160 325	1008 10095 1009 1008				
			795	1.0085	...	...	3.830	.48
25th	20 oz. Strong Montpellier, Harrogate, taken warm at 8 am	8.12 pm 12.4 pm 4.8 pm 8.8 am	150 146 148 314	1008 10102 1009 10092				
			758	1.0089	...	...	3.820	.50
26th	20 oz. Strong Montpellier, Harrogate, taken warm at 8 am	8.12 pm 12.4 pm 4.8 pm 8.8 am	142 145 143 290	10085 1009 10092 10092				
			720	1.009				
27th	20 oz. Strong Montpellier, Harrogate, taken warm at 8 am	8.12 pm 12.4 pm 4.8 pm 8.8 am	120 164 145 319	10085 10102 1009 1009				
			748	1.0091	...	...	4.011	.53

[illegible]

Date.	Ding.	Hours.	BILE in 24 hours.					
			Quantity in c.cms.	Specific Gravity.	Solids.		Bile Salts.	
					Total in Grammes.	Per cent.	Total in Grammes.	Per cent.
1897. Nov- ember 28th	...	8.12 pm 12.4 pm 4.8 pm 8.8 am	138 173 160 339	1009 1009 1009 10085				
			810	1.0088				
29th	20 oz. Kissingen, Harrogate, taken at 8 am	8.12 pm 12.4 pm 4.8 pm 8.8 am	170 181 148 327	1008 1009 10085 10085				
			826	1.0085	16.288	1.95	1.167	.54
30th	20 oz. Kissingen, Harrogate, taken at 8 am	8.12 pm 12.4 pm 4.8 pm 8.8 am	151 212 152 407	10075 10095 10095 10095	...	...	...	...
			922	1.0091	...	...	...	...
Decem- ber 1st	...	8.12 pm 12.4 pm 4.8 pm 8.8 am	152 180 155 361	1009 10095 1008 1009				
			848	1.0089				
2nd	...	8.12 pm 12.4 pm 4.8 pm 8.8 am	144 168 150 350	10092 1010 1009 10087	...	...	...	...
			807	1.0092	...	...	...	...
3rd	20 oz. Old Sulphur Well, Harrogate, taken warm at 8 am	8.12 pm 12.4 pm 4.8 pm 8.8 am	132 188 169 390	10095 10095 1010 1010				
			874	1.0097	18.427	2.08	...	...
4th	20 oz. Old Sulphur Well, Harrogate, taken warm at 8 am	8.12 pm 12.4 pm 4.8 pm 8.8 am	175 179 162 355	10095 1011 1010 10095				
			871	1.0099	18.650	2.12	5.946	.68

URINE in 24 hours.

Quantity in c.cms.	Specific Gravity.	Reaction.	Urea in Grammes.	Uric Acid in Grammes.	Creatinine in Grammes.	Ammonia in Grammes.	REMARKS
...	...	...	...	...	...	...	No albumen or sugar in the urine.
3275	1008	Faintly Acid	23.605				
...	...	...	...	...	...	...	The urine was examined on this and many succe- quent occasions, but no trace of albumen was ever detected.
2524	10105	Acid	19.775				
2164	1011	F. Acid	26.207	.505	.486		
1935	1011	F. Acid	20.170	.510	.421		

Date.	Drug.	Hours.	BILE in 24 hours.					
			Quantity in c.cms.	Specific Gravity.	Solids.		Bile Salts.	
					Total in Grammes.	Per cent.	Total in Grammes.	Per cent.
1897. Decem- ber 5th	20 oz. Old Sulphur Well, Harrogate, taken warm at 8 am	8.12 pm	142	1011				
		12.4 pm	180	10107				
		4.8 pm	156	1010	...	...	...	...
		8.8 am	345	1010				
			823	1.0103	18.675	2.24	5.794	.70
6th	...	8.12 pm	125	10095				
		12.4 pm	195	10085				
		4.8 pm	152	1008				
		8.8 am	351	1008				
			823	1.0083	14.964	1.80	...	...
7th	...	8.12 pm	145	10085				
		12.4 pm	195	10085				
		4.8 pm	163	10085				
		8.8 am	353	1009				
			856	1.0088	16.232	1.88		
8th	20 oz. Soda-Water, taken at 8 am	8.12 pm	160	1009				
		12.4 pm	172	10082				
		4.8 pm	154	1009				
		8.8 am	297	1010				
			783	1.009	16.612	2.10		
9th	...	8.12 pm	144	10095				
		12.4 pm	140	10085				
		4.8 pm	147	1009				
		8.8 am	320	10092				
			751	1.0091	16.246	2.14		
10th	...	8.12 pm	130	1009				
		12.4 pm	171	1008				
		4.8 pm	149	1009				
		8.8 am	292	1009				
			742	1.0088	15.730	2.12	...	...
11th	Benzoate of Soda, 20 grains at 8.15 am	8.12 pm	163	1011				
		12.4 pm	166	1010				
		4.8 pm	181	10095				
		8.8 am	346	10095				
			856	1.0099	18.514	2.16	...	...

URINE in 24 hours.						
Quantity in c.c.m.	Specific Gravity.	Reaction.	Urea in Grammes.	Uric Acid in Grammes.	Creatinine in Grammes.	Ammonia in Grammes.
						REMARKS.
...	...	...	...	...	...	Patient did not feel well. — caught a cold.
2230	1011	F. Acid	19.578	.514	.499	
1602	1011	F. Acid	19.395	.364	.365	
2240	1006	Very F. Acid	13.411	.452	.310	
2000	1009	F. Acid	14.876			
2300	1009	F. Acid	19.993	...	.520	
2071	1008	F. Acid	14.145	...	.317	
1852	1006	Very F. Alkaline	10.154	.254	.238	

Date.	Drug.	Hours.	BILE in 24 hours.					
			Quantity in c.c.m.	Specific Gravity.	Solids.		Bile Salts.	
					Total in Grammes.	Per cent.	Total in Grammes.	Per cent.
1897. Decem- ber 12th	...	8.12 pm	147	1009				
		12.4 pm	161	1010				
		4.8 pm	165	10085				
		8.8 am	341	1009				
			814	1.0091	16.444	2.00	...	...
13th	Salicylate of Soda, 15 grains at 8 am, at 1 and at 4 pm	8.12 pm	143	1010				
		12.4 pm	176	1009				
		4.8 pm	150	1008	...	...	...	...
		8.8 am	316	1009				
			785	1.009	15.794	1.87	...	...
14th	...	8.12 pm	152	1009				
		12.4 pm	173	1010				
		4.8 pm	166	10085	...	...	...	...
		8.8 am	300	1009				
			791	1.0091	...	...	...	...
15th	...	8.12 pm	143	1009				
		12.4 pm	165	1010				
		4.8 pm	147	1009				
		8.8 am	304	1009				
			759	1.0001	15.846	2.06	...	...
16th	...	8.12 pm	136	1009				
		12.4 pm	153	1010				
		4.8 pm	164	10095				
		8.8 am	311	10095				
			764	1.0095	16.364	1.99	...	...
17th	...	8.12 pm	148	1011				
		12.4 pm	151	1009				
		4.8 pm	144	1009				
		8.8 am	281	1010				
			724	1.0095	15.292	2.11	...	...
18th	Euonymin, 4 grains at 1 pm, at 5 and at 9 pm	8.12 pm	130	1009				
		12.4 pm	158	1011				
		4.8 pm	142	1010	...	...	...	...
		8.8 am	280	10105				
			710	1.0101	18.580	2.52	5.840	.80

URINE in 24 hours.

Quantity in c.cms.	Specific Gravity.	Reaction.	Urea in Grammes.	Uric Acid in Grammes.	Creatinine in Grammes.	Ammonia in Grammes.	REMARKS.
1790	1012	F. Acid	16.146	.431	.351		
...	...	...	...	...	...	...	Looking from table and specimen results not normal.
2135	1008	Very F. Alkaline	12.774	.611	.262		
...	...	...	...	...	...	...	Bk. pressure deter- mined 2nd day.
2230	1009	F. Acid	16.994	.325	.401		
2150	1008	F. Acid					
1900	1008	F. Acid	20.914	.478	.407		
1880	1009	F. Acid	16.979	.436	.482		
...	...	...	...	...	...	...	Purged six times during the night. Total urine taken from 12 to 12 and sequently until 10 AM as determined next day.
2200	1004	Neutral	13.660	.688	.421		

Date.	Drug.	Hours.	BILE in 24 hours.					
			Quantity in c.cms.	Specific Gravity.	Solids.		Bile Salts.	
					Total in Grammes.	Per cent.	Total in Grammes.	Per cent.
1897. Decem- ber 19th	Euonymin, 4 grains taken at 8 am	8.12 pm	150	1012				
		12.4 pm	133	1010				
		4.8 pm	165	10085				
		8.8 am	338	1008				
			786	1'0092	...	...	...	...
20th	Euonymin, 2 grs. at 11 am, 2 grs. at 3, and 4 grs. at 9 pm	8.12 pm	175	1008				
		12.4 pm	221	10085				
		4.8 pm	170	1008				
		8.8 am	374	1008				
			940	1'0083	16'015	1'69	4'152	'44
21st	Euonymin, 2 grains taken at 8 am	8.12 pm	188	10085				
		12.4 pm	185	1009				
		4.8 pm	166	1008				
		8.8 am	365	1009				
			904	1'0087	17'314	1'89	5'102	'56
22nd	...	8.12 pm	161	10095				
		12.4 pm	167	1009				
		4.8 pm	170	1009				
		8.8 am	341	1009				
			838	1'0091	16'726	1'99	...	...
23rd	Iridin, 3 grains at 8 am, 12, and 4 pm	8.12 pm	143	1010				
		12.4 pm	192	1010				
		4.8 pm	156	1009	...	...	...	...
		8.8 am	310	1010				
			801	1'0099	...	...	...	...
1898. January 4th	...	8.12 pm	lost					
		12.4 pm	174	10085				
		4.8 pm	157	1009				
		8.8 am	267	10092				
5th	20 oz. Strong Montpellier, Harrogate, taken warm at 8 am	8.12 pm	132	1009				
		12.4 pm	177	1010				
		4.8 pm	151	1008				
		8.8 am	312	1009				
			772	1'0092	15'312	1'97	3'880	'50

URINE in 24 hours.

Quantity in c.cms.	Specific Gravity.	Reaction.	Urea in Grammes.	Uric Acid in Grammes.	Creatinine in Grammes.	Ammonia in Grammes.	REMARKS.
2197	1005	Faintly Alkaline	10.272	.615	.493		
2420	1007	Neutral	16.111	.655	.439	1.193	
2440	1005	Faintly Alkaline	10.034	.558	.575		
2318	1006	Neutral	11.116	.472	.460	1.130	
...	...	...	...	...	...	...	Solids could not be determined owing to an accident with the bile.
2190	1009	F. Acid	15.713	...	.451	1.097	
2350	1005	F. Acid	10.224	.407	.405	1.478	
2415	1006	F. Acid	13.635	.483	.362	1.0469	

Date.	Drug.	Hours.	Bile in 24 hours.					
			Quantity in c.cms.	Specific Gravity.	Solids.		Bile Salts.	
					Total in Grammes.	Per cent.	Total in Grammes.	Per cent.
1898. January 6th	20 oz. Mont- pellier, Harrogate, at 8 am	8.12 pm	147	1009				
		12.4 pm	172	10095				
		4.8 pm	152	10095				
		8.8 am	270	10095				
			741	1.0094	15.325	2.04	...	...
7th	...	8.12 pm	154	1010				
		12.4 pm	177	1009				
		4.8 pm	150	1008	...	...	...	...
		8.8 am	313	1008				
			794	1.0088	15.463	1.92	3.891	.48
8th	20 oz. Kissingen, Harrogate, at 8 am	8.12 pm	131	1009				
		12.4 pm	169	1009				
		4.8 pm	146	1010	...	...	...	...
		8.8 am	310	1009				
			756	1.0092	15.595	2.04	...	...
9th	20 oz. Kissingen, Harrogate, at 8 am	8.12 pm	126	1010				
		12.4 pm	228	10075				
		4.8 pm	170	1008	...	...	...	...
		8.8 am	355	1009				
			879	1.0085	17.107	1.93	5.002	.56
10th	...	8.12 pm	165	10085				
		12.4 pm	213	10075				
		4.8 pm	167	1008				
		8.8 am	346	10072				
			893	1.0077	15.814	1.77	4.028	.45
11th	...	8.12 pm	162	1008				
		12.4 pm	175	1009				
		4.8 pm	155	1009				
		8.8 am	328	10095				
			820	1.009	16.640	2.03	4.610	.56
12th	20 oz. Chloride of Iron Water, Harrogate, at 8 am	8.12 pm	148	10095				
		12.4 pm	164	10085				
		4.8 pm	163	1009				
		8.8 am	322	1009				
			797	1.0092	16.323	2.02	...	...

URINE in 24 hours.

Quantity in c.c.m.	Specific Gravity.	Reaction.	Urea in Grammes.	Uric Acid in Grammes.	Creatinine in Grammes.	Ammonia in Grammes.	REMARKS.
1960	1010	F. Acid	15.047	.499	.421		
...	...	...	...	...	...	...	Patient troubled with flatulence.
1984	1009	F. Acid	21.288	.544	.452		
...	...	...	...	...	...	...	Patient had very severe spasms all night.
2025	1006	Neutral	14.238	.583	.376		
...	...	...	...	...	...	...	Patient felt very well to-day.
2600	1005	Neutral	14.530	.589	.370		
2530	1009	F. Acid	13.567	.534	.353	1.2376	
2597	1004	Neutral	9.974	.514	.341	1.433	
2340	1010	Acid	20.077	.589	.449	1.051	

Date.	Drug.	Hours.	BILE in 24 hours.					
			Quantity in c.cma.	Specific Gravity.	Solids.		Bile Salts.	
					Total in Grammes.	Per cent.	Total in Grammes.	Per cent.
1898. January 13th	20 oz. Chloride of Iron Water, Harrogate, at 8 am	8.12 pm	136	10085				
		12.4 pm	182	10102				
		4.8 pm	148	1010				
		8.8 am	353	1010				
			819	1·0098	18·305	2·18	5·241	·64
14th	...	8.12 pm	150	1011				
		12.4 pm	240	1009				
		4.8 pm	150	10085				
		8.8 am	324	10095				
			864	1·0094	19·457	2·25	...	...
15th	20 oz. Hot Water, at 8 am	8.12 pm	134	10095				
		12.4 pm	155	1009				
		4.8 pm	157	1009				
		8.8 am	339	1009				
			785	1·0091	16·519	2·09	4·207	·53
16th	...	8.12 pm	150	1009				
		12.4 pm	171	1008				
		4.8 pm	153	1009				
		8.8 am	330	1009				
			804	1·0089	16·400	2·04	...	...
17th	Salicylate of Soda, 15 grains at 9.30 am, at 1 and at 5 pm	8.12 pm	158	10092				
		12.4 pm	171	1009				
		4.8 pm	159	10085				
		8.8 am	355	1009				
			843	1·0089	17·905	2·11	5·462	·68
18th	Salicylate of Soda, 15 grains at 10 am, at 2 and 6 pm	8.12 pm	135	1010				
		12.4 pm	162	1011				
		4.8 pm	145	1010	...	...	...	...
		8.8 am	310	1009				
			752	1·010	16·526	2·17	...	...
19th	...	8.12 pm	142	1009				
		12.4 pm	165	1009				
		4.8 pm	154	1010				
		8.8 am	311	1010				
			772	1·0105	18·311	2·34	5·774	·74

URINE in 24 hours.							REMARKS.
Quantity in c.cms.	Specific Gravity.	Reaction.	Urea in Grammes.	Uric Acid in Grammes.	Creatinine in Grammes.	Ammonia in Grammes.	
2310	1006	F. Acid	15·661	·549	·435		
2310	1007	F. Acid	16·966	·511	·418	1·0595	
2008	1010	F. Acid	20·874	·553	·428	1·1079	
2315	1008	F. Acid	18·771	·524	·366		
2138	1008	Neutral	15·757	·881	·390		
...	...	...	...	...	...	...	Patient had indigestion.
2177	1010	F. Acid	19·237	·819	·414	1·0825	
2859	1007	Neutral	12·933	·685	·451		

Date.	Drug.	Hours.	BILE in 24 hours.					
			Quantity in c.cms.	Specific Gravity.	Solids.		Bile Salts.	
					Total in Grammes.	Per cent.	Total in Grammes.	Per cent.
1898. January, 20th	...	8.12 pm 12.4 pm 4.8 pm 8.8 am	134 136 127 273	1010 1011 1013 1010				
			670	1.012	15.304	2.25	3.832	.56
21st	Podophyllo-resin, grain $\frac{1}{4}$ at 1 and 5 and at 8 pm	8.12 pm 12.4 pm 4.8 pm 8.8 am	129 140 158 283	1013 1014 1012 1013				
			710	1.013	18.857	2.63	...	...
22nd	Podophyllo-resin, grain $\frac{1}{4}$ at 8 am, at 12, and at 4 pm	8.12 pm 12.4 pm 4.8 pm 8.8 am	138 165 184 292	1014 1011 1011 1011				
			779	1.0115	18.571	2.34	5.774	.73
23rd	...	8.12 pm 12.4 pm 4.8 pm 8.8 am	132 189 169 327	10105 1010 1009 10095				
			817	1.0095	17.091	2.08	...	...
24th	...	8.12 pm 12.4 pm 4.8 pm 8.8 am	145 157 172 300	1009 10082 10075 1008				
			774	1.0079	15.139	1.98	...	...
25th	Podophyllo-toxin, grain $\frac{1}{4}$ at 8 am, 12, 4 and 8 pm	8.12 pm 12.4 pm 4.8 pm 8.8 am	139 173 152 294	1008 1009 1008 1008	...	...	...	...
			758	1.0082	14.311	1.88	4.044	.56
26th	...	8.12 pm 12.4 pm 4.8 pm 8.8 am	136 137 147 280	10085 10085 10085 1009				
			700	1.0087	13.944	1.99	...	...

URINE in 24 hours.

Quantity in c.cms.	Specific Gravity.	Reaction.	Urea in Grammes.	Uric Acid in Grammes.	Creatinine in Grammes.	Ammonia in Grammes.	REMARKS.
1993	1010	Neutral	12.160	.501	.473		
1908	1012	F. Acid	19.187	.542	.430	1.1736	
1938	1008	F. Acid	17.644	.520	.410	1.0987	
2100	1005	Faintly Alkaline	11.152				
2152	...	Alkaline					
...	...	...	...	...	...	...	The urine was feebly acid when passed; bowels acted twice.
2200	...	Alkaline					
2180	1007	Neutral	15.183	.564	.409		

Date.	Drug.	Hours.	BILE in 24 hours.					
			Quantity in c.cms.	Specific Gravity.	Solids.		Bile Salts.	
					Total in Grammes.	Per cent.	Total in Grammes.	Per cent.
1898. January 27th	...	8.12 pm 12.4 pm 4.8 pm 8.8 am	140 152 157 266	1009 10095 10095 1010				
			715	1.0097	16.016	2.23	4.631	.64
28th	10 oz. Carlsbad at 8 am, and 10 oz. at 8 pm	8.12 pm 12.4 pm 4.8 pm 8.8 am	139 163 170 321	10095 1010 10095 10105	...	...	...	...
			793	1.010	18.312	2.28	5.392	.68
29th	Carlsbad Mineral- Water, 6 oz. at 8 am and 4 oz. at 8 pm	8.12 pm 12.4 pm 4.8 pm 8.8 am	158 170 174 326	10087 10095 10095 10097				
			826	1.0094	18.393	2.20	5.729	.69
30th	...	8.12 pm 12.4 pm 4.8 pm 8.8 am	146 180 172 306	1007 1008 10075 1008				
			804	1.0075	15.862	1.88	4.020	.50
31st	...	8.12 pm 12.4 pm 4.8 pm 8.8 am	135 165 168 285	10095 10095 10082 1009				
			753	1.0089	16.212	2.12	4.520	.60
Feb- ruary 1st	Iridin, 3 grains at 9 am, at 1 and at 5 pm	8.12 pm 12.4 pm 4.8 pm 8.8 am	139 150 155 300	10095 1010 1009 1010				
			744	1.0089	16.849	2.24	5.088	.68
2nd	Iridin, 3 grs. three times a day.	8.12 pm 12.4 pm 4.8 pm 8.8 am	150 187 184 307	10095 1009 10095 1010				
			828	1.0099	18.679	2.47	...	...

URINE in 24 hours.							REMARKS.
Quantity in c.cms.	Specific Gravity.	Reaction.	Urea in Grammes.	Uric Acid in Grammes.	Creatinine in Grammes.	Ammonia in Grammes.	
2050	...	Alkaline					
...	...	...	...	...	...	...	Purged seven times during the night.
1900	1009	F. Acid	18·358	·573	·432	1·0489	
2255	...	Alkaline					
2011	1004	Neutral	11·588	·444	·422		
2000	1009	Neutral	14·463	·550	·396		
1910	1010	Neutral	14·138	·534	·439		
1890	1004	Neutral	10·030	·512	·417		

The influence of Drugs on the Secretion of Bile.—Before describing my results it would be advantageous to refer very briefly to the experiments performed on dogs in relation to this subject.

Nasse (20) was the first to investigate cholagogues. He gave one gramme of calomel to a dog with a permanent biliary fistula, and came to the conclusion that calomel increased the quantity of bile, but diminished the bile solids.

Köl liker and Müller (21) tried calomel and aloes without effect.

Mosler (22) and Scott (23) found that calomel did not increase the amount of bile; indeed, the latter said it produced a diminution in the quantity and in the solids. These four experimented on dogs with permanent biliary fistula.

The committee, of which Hughes Bennett (24) was chairman, decided that mercuric chloride, calomel and pil hydrargyri did not increase the flow of bile.

Böhrig (25) experimented on curarised dogs and rabbits. He counted the drops of bile flowing from the canula inserted into the opened gall-bladder,—a method open to criticism. Moreover, he gave such large doses (30 drops of croton oil) that his results must be of little value.

Rutherford's (26) elaborate researches are so well known that a resumé is unnecessary. Rutherford asserts that whatever increases the quantity of bile, similarly affects the solids; and for that reason he did not consider it necessary to estimate the solids in the greater number of his experiments. I maintain that there are drugs which increase the solids without materially affecting the quantity of the bile; therefore it is incumbent upon the investigator to estimate the solids in all his experiments. Further, I consider the total solids are a more important guide to the influence of a drug on the liver than the quantity of bile secreted. Rutherford attaches great importance to the relationship existing between the quantity of bile secreted and the body-weight of the animal. He bases almost all his conclusions upon this supposed relationship—a relationship, however, which is disproved by referring to Table I. Apart from these criticisms, my results, so far as they go, confirm in the main Rutherford's experiments.

Rosenberg (27) used dogs with permanent biliary fistulæ. He found salicylate of soda, olive oil and fats to be cholagogues, the last two being the most powerful. Durand's mixture and Carlsbad salts gave negative results.

Battistini (28) found santonin to be the best cholagogue, and in this is corroborated by Marfori.

Prevost and Binet (30) declared that bile itself was the most powerful cholagogue, but turpentine, chlorate of potash, benzoate and salicylate of soda, salol, euonymin and muscarin were effective. Amongst doubtful substances they placed Carlsbad salts.

Baldi (31) tried podophyllin, rhubarb, jalap, sodium phosphate, pilocarpine, and Carlsbad water without effect, but ox-bile increased the amount and the solids.

Kunkel (32) tried large quantities of water, but the quantity of bile was not increased, nor were the solids affected.

Lewaschew (33) found salicylate of soda effectual.

Paschkis (34) and Niessen (35) obtained negative results with all cholagogues except bile. Since 1890 Stadelmann, and his pupils Niessen, Mandelstamm (36), Müller (37), Lowenton (38), and Glass (39) have conducted a series of careful investigations of cholagogues. Stadelmann (40), summarising the results of these investigations, shows that bile, and possibly salicylate of soda, alone act as cholagogues. He strongly condemns the practice of drawing comparative conclusions regarding the secretion of bile from experiments extending over short periods of time.

Gamgee, commenting on the diversity of these results, suspends his judgment until a fresh research is undertaken on dogs by means of Schiff's amphibolic biliary fistulæ. While I agree with him regarding the value of evidence derived from experiments carried out by Schiff's method, it is my belief that fairly reliable results can be obtained in cases of human biliary fistula by the administration of ox-bile during the entire investigation. Further, although dogs are more easily controlled than human beings as regards food, liquid, and exercise, it is a much more difficult matter in their case to collect the bile without loss.

In Table II. I have drawn up a series of averages, which will help to elucidate my conclusions. Some of the estimations of the bile salts unfortunately miscarried, so that on several occa-

sions the average of bile salts is for a less number of days than those on which a particular drug was given. This also applies in a few instances to the bile solids.

TABLE III.—*Showing the average amount of Bile, Bile Solids, and Bile Salts on the days during which certain Drugs or Mineral-Waters were given.*

Drugs Administered.	Quantity of Bile in c.cms.	Bile Solids.		Bile Salts.	
		Total in grammes.	Per cent.	Total in grammes.	Per cent.
Without Medication, .	775	15·393	2·07	4·197	·55
Old Sulphur Spring, .	878	18·584	2·14	5·870	·69
Kissengen Spa, . .	845	16·330	1·97	4·734	·55
Carlsbad Mineral-Water,	809	18·352	2·24	5·560	·68
Euonymin, . . .	836	17·300	2·03	5·031	·60
Benzoate of Soda, . .	856	18·514	2·16	...	...
Salicylate of Soda, . .	797	17·215	2·14	5·462	·68
Iridin,	788	17·764	2·35	5·083	·68
Podophyllo-resin, . .	744	18·714	2·48	7·774	·73
Podophyllo-toxin, . .	758	14·311	1·88	4·044	·56
Strong Montpollier Spa, .	747	15·318	2·00	3·853	·50
Chloride of Iron Spa, .	808	17·314	2·10	5·241	·64
Pint of Hot Water, .	785	16·519	2·09	4·207	·53
Pint of Soda-Water, .	783	16·612	2·10	...	...

The influence of the Harrogate mineral-waters on the secretion of bile has never been tested experimentally; and as I am interested in this particular branch of therapeutics, I began the investigation with them. It should be stated that the waters were sent up to London in bottles, and kept in the laboratory some time before being used.

The Old Sulphur Spring.—The strong sulphur water generally acts as a mild laxative. If the bowels are moved naturally once

a day, the only difference it causes, as a rule, is that the evacuations are more copious, and this was the effect upon my patient. An average of four days gave 878 c.c. of bile, with 18·5 grammes solid.

There is no doubt that this water has a very decided effect on the secretion and composition of bile, and I shall show in another paper that this effect is probably due to stimulation of the hepatic cells. As this water contains sulphuretted hydrogen gas, it is possible the effect would have been greater had it been taken at its source.

No other drug or mineral-water with which I experimented produced such a striking increase in both the quantity of bile and bile solids as the Old Sulphur Spring.

Strong Montpellier Spring.—The average of five days shows a diminution in the quantity of bile, in the bile solids, and bile salts; therefore, this water is not a cholagogue. Hunter, in *Allbutt's System of Medicine*, asserts that the beneficial effects of most of the natural mineral-waters are due to a flushing out of the biliary system. In the face of this and other experiments, it is difficult to see how his hypothesis can be maintained.

Kissingen Spa.—The average of four days shows a distinct increase in the quantity of bile, and a slight increase in the solids. The patient had a sharp attack of flatulent dyspepsia one night when he was taking this water, which necessitated the administration of two small doses of brandy. If this day's secretion be omitted, the average rises to 875 c.c. of bile, with 16·6 grammes solids; therefore, the action of the Kissingen water is to increase considerably the quantity of bile without materially augmenting the total solids.

Chloride of Iron Spa.—This water is prescribed for cases of anæmia. It was given to test the alleged effect of iron in reducing the quantity of bile. It should be stated, however, that in addition to iron, it contains a large quantity of chloride of sodium, and appreciable quantities of chlorides of calcium, magnesium, barium, and potash. The dose given was much larger than usual, but it did not disagree. The average of 808 c.c. is somewhat misleading. The day before commencing the water, the quantity of bile was 820 c.c., and the day after it was stopped the quantity rose to 864 c.c. and the solids to

19.457 grammes. It was my intention to have repeated this experiment, but time did not permit. The marked rise, both in the quantity and the solids, on the day after the last administration is a feature of interest.

In regard to the Harrogate waters, it is a point of clinical interest that the relative empirical reputations of the Old Sulphur and the Strong Montpellier Springs are experimentally sustained.

Carlsbad. Mineral-Water.—The patient took 10 oz. before breakfast and 10 oz. at bedtime. The second dose purged him seven times. The next day he had 6 oz. before breakfast and 4 oz. at bedtime. The average of the two days gave 808 c.c. of bile, with 18.3 grammes solids. The quantity would be higher were it not for the depletion produced by the purging.

Notwithstanding the negative results obtained by other investigators, I have no hesitation in saying that the high esteem in which this mineral-water is held as a cholagogue is undoubtedly deserved.

A Pint of Hot Water before Breakfast.—This was given on one occasion. The result was 785 c.c. of bile, with 16.5 grammes solids.

A Pint of Soda-Water before Breakfast.—This was also taken on one occasion. The result was 783 c.c. of bile, with 16.6 grammes solids.

In both instances the quantity of bile was scarcely affected, but there was a very slight increase in solids.

Euonymin.—The average of five days gave 836 c.c. of bile, with 17.3 grammes solids; but this does not convey an accurate idea of its effect in relation to the quantity. The patient took 12 grains on the first day, which purged him six times, with a consequent diminution in the quantity of bile, which spoilt the average. It is interesting to note that the solids were the highest on this day. On the last two days the drug was taken the quantity was 940 c.c. and 904 c.c. respectively—a very considerable increase; therefore, euonymin unquestionably increases the quantity of bile, and, to a less extent, the bile solids.

Iridin.—The average of four days gave 788 c.c. of bile, and the average of two days 17.7 grammes solids. From a consideration of these figures, one can safely say that iridin does affect

the complex chemical processes which take place in the liver, without increasing the quantity of the bile.

Benzoate of Soda.—This drug was exhibited on one occasion, and in one dose of 20 grains. The result was 856 c.c. of bile, with 18.5 grammes solids. It is undesirable to express an opinion regarding the efficacy of a drug from merely one observation, but I should like to point out that the considerable rise in the total solids can scarcely be regarded as a coincidence, because during the days without medication the solids never exceeded 17 grammes.

Salicylate of Soda.—An average of two days gave 797 c.c. of bile, with 17.2 grammes solids; and the day after the discontinuance of the drug the solids rose to 18.3 grammes; therefore there can be no doubt that it does influence the metabolism of the liver. During its administration the patient suffered a part of one day from indigestion, which might possibly have inhibited the biliary secretion.

With one exception (Niessen), all investigators are agreed that this substance increases the secretion of bile.

Podophylloresin.—This is a resinous subject extracted from *Podophyllum Emodi* by Professor Dunstan (42), for a sample of which I am indebted to Dr Dixon. It was given in non-purgative doses. The average of two days gave 744 c.c. of bile, with 18.7 grammes solids. This is rather misleading as regards quantity. The day before the drug was given the quantity was only 670 c.c., the first day of administration 710 c.c., the second day 779 c.c., and the day after its discontinuance the quantity rose to 817 c.c., with 17 grammes solids. The increase in the solids is the highest of all substances tested, therefore I think this drug has a decidedly stimulating effect on the liver.

Podophyllotoxin.—This is another extract of *Podophyllum Emodi*, also extracted by Professor Dunstan (42). It was given on one occasion, and although the doses were supposed to be non-purgative it acted twice on the bowels. The result was 758 c.c. bile, with 14.3 grammes solids, and the day after the solids fell to 13.9 grammes, the lowest during the investigation; consequently, this substance seems to have an adverse influence on the biliary secretion.

Analysis of the Urine.—It was not deemed desirable to ask

the patient to bring his urine until he became familiar with collecting his bile. The object in analysing the urine was to get an approximate idea of the amount of nitrogen excreted, and thereby an indication of the quantity of nitrogenous food assimilated. This end could be more accurately attained by adopting some modification of Kjeldahl's process, but I wished to ascertain the action of the drugs used on the excretion of urea and uric acid. Unfortunately, the urine was frequently either neutral or faintly acid, so that conclusions drawn from the results obtained would probably be fallacious. Various expedients were tried to prevent its decomposition, but without much success. The quantity of urine was above the average—about 2000 c.c.—and the specific gravity rarely exceeded 1.010. The colour, considering the quantity, appeared to be normal. Although it was examined repeatedly for albumen, no trace was detected.

For the estimation of urea, Hufner's hypobromite method was employed.

For estimating uric acid, Hopkins' long process was used until January 7th, when I tried Otto Folin's modification of Hopkins' short method. This consists essentially in substituting 10 grammes of ammonium sulphate for saturation with ammonium chloride in a 100 c.c. of urine, and subsequently washing the precipitate with a 10 per cent. solution of ammonium sulphate instead of a saturated solution of ammonium chloride. Folin's method is expeditious, but I do not think it is reliable when the urine is concentrated, and it was found with the dilute urine of my patient that two hours were insufficient for complete precipitation. The uric acid was observed to be increased while the patient was taking salicylate of soda, and, to a slight extent, during the administration of euonymin. Noel Paton found that euonymin increased, while salicylate and benzoate of soda markedly diminished the excretion of uric acid. Hopkins, in Schäfer's *Physiology*, states that the salicylates undoubtedly increase the quantity of uric acid in the urine.

For estimating creatine, Johnson's method was adopted; but a very small amount of the mercurial compound always adhered to the flask, hence a margin of error is introduced into the result.

For the estimation of ammonia, Schliesing's method was adopted; but it is unsatisfactory for clinical purposes because of the length of time required. As the urea kept persistently below the normal in this case, it was considered probable that the ammonia would be increased in consequence of the diminished formation of urea. Neubauer found the quantity of ammonia to vary in health from .3 to 1.2 grammes in the twenty-four hours and this has been confirmed by later observers. In my patient it varied from 1.04 to 1.4 grammes, but it is doubtful whether this slight augmentation is due to the feeble reaction of the urine, or to diminished functional activity of the liver.

SUMMARY OF CONCLUSIONS.

1. The amount of bile secreted in the twenty-four hours in a man somewhat below medium height and weight averages 770 c.c., and the bile solids 15.8 grammes.
2. More bile is secreted during the day than at night.
3. The sulphocyanate of potash in the saliva is not derived from the biliary salts.
4. The following substances increase both the quantity of bile and bile solids:—Old Sulphur Spring (Harrogate), Carlsbad mineral-water, euonymin, benzoate of soda, salicylate of soda, and Kissingen Spa (Harrogate).
5. Podophylloresin and Iridin augment the bile solids without appreciably affecting the quantity of bile.
6. Strong Montpellier Spring (Harrogate) and Podophyllo-toxin appear to diminish slightly both the quantity and the solids.
7. Hot water and soda-water in pint doses do not seem to increase the biliary secretion.
8. Salicylate of soda increases the excretion of uric acid in the urine.

- (4) MURCHISON, *Diseases of the Liver*, 3rd edition, p. 574.
- (5) FRERICH'S *Klinik der Leberkrankh.*, Bd. II, p. 151.
- (6) RANKE, *Die Blutvertheilung und die Thätigkeit der Organe*, Leipzig, 1871, chap. viii.
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THE PERIPHERAL DISTRIBUTION OF THE CRANIAL
NERVES OF AMMOCETES. By R. ALBERT BATHING
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I. THE BRANCHIAL NERVES, AND THE INNERVATION OF THE
LATERAL LINE SYSTEM.

INTRODUCTION.

IN connection with Gaskell's (30) views on the ancestry of Vertebrates, it was essential to have a more exact and detailed knowledge of the distribution of the cranial nerves of Ammocoetes than already existed, in order to institute a comparison between the peripheral nervous system of this primitive vertebrate and that of the invertebrate arthropod type.

Many contradictory statements have been made concerning the peripheral nervous system of Cyclostomes, and our information on the subject, especially in the case of Ammocoetes, is still far from complete in many respects.

The older researches of Rathke (1 and 2, Bonn 11. and 12.) and Schlemm and d'Alton (4), give us the main facts concerning the cranial nerves of *Petromyzon*. Amongst more recent authors Ahlborn (12) has given a most complete description of the brain and the origin of the cranial nerves of *Petromyzon fluviatilis*; and Fürbringer's (6) wonderfully accurate account of the cranial nerves and the muscles innervated by them, from his dissection of *Petromyzon fluviatilis*, remains unrivalled. Finally, Dohrn (19) and von Kupffer (21), in their embryological works have added to our knowledge of the details in Ammocoetes.

As far as I know, there is no complete account of the peripheral distribution of the cranial nerves of Ammocoetes, and only the scantiest description of the muscles innervated by them. So many writers, in their descriptions of *Petromyzon*, only refer somewhat casually to the conditions in Ammocoetes, which, however, present considerable and most instructive differences from those of the adult form.

After reading the literature of the subject, the following points seemed to me to require further investigation :—

1. The innervation of the tentacles round the mouth, and of the median ventral ridge.

2. The innervation of the epithelial pit sense organs on the head and the branchial region of the body.

3. The peripheral distribution of the facial nerve, which is said by Fürbringer (6) and others to be purely sensory.

4. The innervation of the thyroid gland, which, according to Julin (17), is supplied by a branch from the glosso-pharyngeal and branches from the three anterior divisions of the vagus, a condition which Dohrn (19) considers highly improbable for embryological reasons, though he is unable to state by which cranial nerve it is supplied.

5. The exact innervation of the branchial muscles, and whether there is a *ramus prætremaicus* and a *ramus posttremaicus* belonging to the facial, to the glosso-pharyngeal and to each of the divisions of the vagus, as stated by Born, Schlemm, and d'Alton, in *Petromyzon*, and by Julin, in *Ammocoetes*, and denied by Dohrn.

6. The destination of the lateral line branch of the vagus, together with the *recurrens facialis*.

7. The limits of the vagus in the alimentary canal.

8. The existence of a sympathetic system, as described by Ransom and Thompson (16), and by Julin (17).

In the following paper, I shall deal with the distribution of the branchial nerves of *Ammocoetes*, including the facial, the glosso-pharyngeal, and the vagus, together with the arrangement and innervation of the sensory epithelial pits on the head and the branchial region of the body, and leave the other points mentioned for future consideration.

METHODS.

Since *Ammocoetes* is too small for a dissection of the nerves to be possible, I have followed the course and distribution of the cranial nerves, by means of serial sections, from their origin in the brain, as far as possible, to their final destination.

The fact that the nerves of *Ammocoetes* are non-medullated

adds to the difficulty of the work, making staining in osmic acid useless for the purpose of differentiating nerve fibres from other tissues. I tried various staining methods; for instance, osmic acid, hæmatoxylin, borax carmine, and nigrosin, but always came back to picro-carmine, as being the most satisfactory for my purpose. With this stain the outer sheath of the nerve fibre and the nuclei are coloured deep red, whilst the axis-cylinder is yellowish. At the same time, I had to contend with unexpected difficulties in the use of picro-carmine, owing to the action of picric acid on the laminated layer of the skin. After leaving a piece of the animal in picro-carmine for several days at a temperature of 60° C., I found the laminated layer of the skin had completely disappeared, having been dissolved by the prolonged action of the picric acid. A less prolonged action causes this layer to become granular and very hard, and extremely difficult to cut.

In the spinal nerves, it is quite easy to distinguish between motor and sensory fibres by reason of their difference in size; but in the cranial nerves, the fibres are all extremely small, and though they vary in size, I am unable to group them into motor and sensory fibres, according as they are larger or smaller. For instance, in the purely sensory nerve, the ophthalmic branch of the trigeminal, the difference in size of the fibres is considerable within certain limits, whilst the fibres of the mixed branches of the vagus are all extremely small.

With regard to this question of the size of the fibres, it is most interesting to notice that on transformation from *Ammocetes* into *Petromyzon planeri*, the large increase of motor nerve fibres, which supply the newly-formed muscles, are of an enormous size compared to the older motor fibres.

THE FACIAL NERVE.

The facial nerve, on leaving the brain, enters the auditory capsule with the VIIIth nerve; it leaves the auditory capsule, as Ahlborn (13) has shown, by a small orifice in the ventral side, at the anterior and internal angle. It immediately joins a ganglion, the posterior part of which lies beneath the auditory capsule, whilst the anterior part swells out in front of it (Pl. II. figs. 1 and 2.)

The anterior portion of the ganglion, consisting of large nerve cells, gives rise to four nerves. The most considerable of these is the *ramus recurrens facialis*, described by Fürbringer (6) in *Petromyzon*, and called by Schlemm and d'Alton (4) the 'ramus posterior.' In *Ammocoetes*, just as in *Petromyzon*, the *ramus recurrens* (figs. 1 and 2), on leaving the ganglion, curves outwards round the anterior end of the auditory capsule, and runs posteriorly, along the external side of the capsule, between the dorsal and ventral portions of the first dorsal myomeres. At the posterior end of the capsule it turns inwards to join the lateral line branch of the vagus. The lateral line nerve, thus formed by the union of the *ramus recurrens facialis* and a portion of the vagus, possesses a ganglion separate from that of the branchial portion of the vagus, and runs between the connective tissue surrounding the spinal cord and the dorsal mass of the body muscles. It retains this position right up to the end of the tail, gradually diminishing in size. The peripheral distribution of the lateral line nerves is only partially known, in spite of all the discussion as to their homology with the lateral line nerves of *Selachians*. From embryological considerations Dohrn (19) says of these nerves: "es ist wohl sehr wahrscheinlich, dass sie mit der Bildung der zuerst von Langerhans nachgewiesenen Grübchen der so-geannten Seitenorgane zusammenhängen." I hope at some future time to show that this is the case; but, so far, I have only examined the lateral line in the branchial region, and have failed to find any branches leaving it in that part of its course.

Langerhans (5) gives a figure of one of these epithelial pits belonging to the lateral line system in *Ammocoetes*; he also describes the arrangement of the pits on the dorsal and ventral surfaces of the body, but he gives no account of their innervation. On the ventral side there is a row of pits on either side of the middle line, beginning near the edge of the lower lip, and continuing back to the posterior end of the branchial basket. On the dorsal side a single row on either side of the head starts near the edge of the upper lip and passes straight back, at the level of the division between the dorsal and the ventral portion of the first myomere, where, on transformation, the eye comes to the surface. On transformation, Langerhans

describes the line of pits as becoming broken, so as not to pass across the eye; in the region of the eye the line then divides into two, some pits being above and some below the eye. This line of pits ceases behind the auditory capsule. In the branchial region of the body there is a row of pits just above the external branchial openings, a more scattered row at some distance above these, and a few pits near the median dorsal line. Behind the branchial region a row of pits, close to the median dorsal line, continues to the end of the tail (fig. 1).

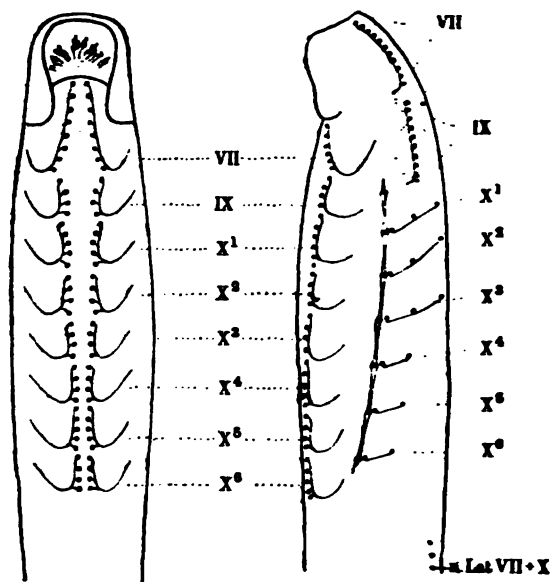


FIG. 1.—Diagram of A, ventral surface, and B, lateral surface of *Ammocetes*, showing the arrangement of the epithelial pits on the branchial region, and their innervation by VII the facial, IX the glosso-pharyngeal, and $x^1 - x^6$ the vagus nerves.

The second large nerve which leaves the anterior end of the ganglion of the facial is the *ramus ophthalmicus superficialis*. This branch was observed by Schlemm and d'Alton (4) in *Petromyzon*, and its presence confirmed by Fürbringer (6) and later observers, who describe it as a sensory branch to the upper lip. It runs forwards between the eyeball and the floor of the orbit, and on reaching the anterior side of the eye it turns outwards and runs forwards, just under the skin, as far as the

anterior edge of the upper lip. This *ramus ophthalmicus* supplies ten or twelve epithelial pits which form the most anterior part of the row on either side of the median dorsal line of the head (fig. 1). It is a special sensory nerve, and is concerned only with the innervation of sense organs belonging to the lateral line system.

A third nerve leaves the ganglion of the facial close to the *ophthalmicus superficialis*: this is an extremely small nerve, and it supplies one epithelial pit on the head, near the median dorsal line above the eye (Pl. II. figs. 1 and 2).

The fourth nerve leaving the anterior end of the ganglion has been repeatedly described. It is a small nerve, which runs dorsalwards to join the ganglion of the ophthalmic portion of the trigeminal. I have failed to follow it through the ganglion, so have no information to add as to its meaning or destination.

With the exception of this last-mentioned nerve, it is seen that all the branches of the facial I have described so far are special sensory nerves, being concerned solely with the innervation of lateral line organs. Still another branch of the facial (fig. 1, A. vii.) supplies some of these organs, but this will be described later with the *ramus hyoideus*, which it leaves, to pass to the ventral surface.

From the posterior portion of the ganglion of the facial passes the large nerve called by Fürbringer (6) the *ramus posterior*, and by Dohrn (19) the *ramus hyoideus*. Fürbringer, in his description of *Petromyzon fluviatilis*, states that the facial is entirely sensory; and concerning the *ramus posterior*, he says it runs "zwischen den dorsalen und ventralen Portion des Seitenrumpfmuskels unter die Haut, in dieser sich zwischen Auge und 1 Kiemenloch verästelnd." Julin (17) says, on the other hand, "Je ne veux nullement contester qu'il n'emané du rameau postérieur des branches nerveuses sensibles, qui vont se distribuer à la peau de cette région, bien que je ne l'aie pu les suivre avec certitude. Mais ce qui a échappé à Fürbringer et à tous ses prédécesseurs c'est que le rameau postérieur du facial constitue le *nerf branchial*, qui va fournir aux lames délimitants en avant et en arrière la première fente branchiale." He then describes it as dividing into a *ramus prætrematicus* and a *ramus posttrematicus*, the

former ending near the first external branchial opening, and the latter passing beneath the gill- slit to end on the other side of it; and he compares this arrangement with the distribution of the facial in Selachians.

With regard to this point, Dohrn (19) says: "Der Widerspruch zwischen Julin und Fürbringer klärt sich, wie mir scheint, einfach und befriedigend auf: der Letztere hat den Ramus mandibularis externus als den eigentlichen facialis betrachtet während Julin mit Recht den vom Gemeinschaftlichen Stamm nach hinten sich abzweigenden Ramus hyoideus, oder wie er ihn nennt, Ramus prætremaicus, als den einen Hauptast des Facialis behandelt. . . . aber problematisch bleibt offenbar noch immer, woher Julin seines Ramus posttremaicus beschafft hat, den er sogar für der Hauptast des Facialis erklären muss, will er anders die behauptete Homologie mit den Selachiern durchführen. Freilich, der R. prætremaicus des Facialis der Selachier entspricht durchaus nicht dem von Julin als R. prætremaicus angesehenen nerven des Ammocetes; bei den Selachiern ist dieser Nerv klein und vor allen Dingen kreuzt er das Spritzloch an seiner oberen contour, nicht wie bei Ammocetes an der unteren. Aber trotz der ziemlich mangelhaften Beschreibung und sehr schematischen Abbildung, die Julin von diesen Nerven, wie sie ihm erschienen sind, giebt, ist es doch möglich, auch seinen R. posttremaicus zu finden. Es geht nämlich, vom Ramus hyoideus, nahe an seinem Ursprung aus dem Ganglion, ein Zweig in nahezu horizontaler Richtung dicht unter dem Knorpel der Ohrblase in die hier weit nach rückwärts verschobene musculatur des Hyoidbogens hinein, kreuzt, somit, da auch diese Musculatur über die obere Seite der Kiemenspalte immer hinüber rät, diese Kiemenspalte, also die eigentliche erste definitive Spalte, die mit der Hyoidspalte der Selachier homolog ist, verläuft aber ausschliesslich in Muskelbezirken des Hyoidbogens. Dieser Ast des Ramus hyoideus, welche nicht mit dem sehr viel stärkeren, höher, d. h. auf der äusseren oberen Grenze der Ohrblase gelegenen Ramus recurrens facialis zu verwechseln ist, da er unter der Ohrblase hinzieht, ist freilich eben so wenig ein Ramus posttremaicus, wie der oben beschriebene ein Ramus prætremaicus des Facialis sein kann — aber es scheint mir

sehr wahrscheinlich, dass es dieser Ast ist den Julin gesehen und seiner Deutung zu Grunde gelegt hat."

Hatschek (24) calls this portion of the facial the *ramus ventralis*, and considers it a typical branchial nerve, belonging to the pseudo-branchial groove, and describes it as giving off a *ramus posttrematicus* and a *ramus prætrematicus*, which latter sends a branch to the sense organ described by v. Kupffer (21).

Kupffer (26), in his embryological work on *Ammocetes*, mentions the branch of the facial, which Dohrn suggests may possibly be Julin's *ramus posttrematicus*, and calls it the *nervus branchialis profundus*, adding that it gives off branches to the large branchial vessels.

Bearing in mind all these conflicting statements, the study of this nerve proved to be of the greatest interest.

In order to facilitate the description of the branchial nerves, I shall adopt Gaskell's (30) suggestion, and consider the branchial region as consisting of a series of segments, adopting as the unit the branchial cartilage and its attendant structures of muscle, nerve, and blood-vessels, etc., rather than the gill-slit. In *Ammocetes*, each such segment (fig. 2) consists of an external portion containing the branchial cartilage and the constrictor muscles, and of an internal portion projecting into the branchial chamber, and connected with the external portion by a narrow neck of connective tissue.

This internal portion is known as the diaphragm, and bears on each side the branchial lamellæ; it also contains the afferent and efferent branchial vessels and the adductor muscle. On the posterior side of the innermost tip of the diaphragm, which is free from branchial folds, are situated the sense organs (fig. 2, S.), which are probably of the nature of taste buds. There are usually five on each diaphragm, as shown in fig. 4, Pl. II.

The branchial muscles of *Ammocetes* have been recently described by Dohrn (19), and more in detail by Nestler (22). The outer branchial muscles or constrictors (fig. 2, *m.c.s.* and *m.c.t.*) consist of two distinct sets of fibres, one set being striated and the other set the peculiar hollow or tubular fibres described by Schneider (7) and Langerhans (5), having a central granular protoplasmic core containing round nuclei, and an external

striated ring. The striated fibres run in an arch shape on the inner side of the branchial cartilage, and are firmly attached to it by its perichondrium. The inner diaphragm muscle, the adductor, which is also striated, passes, on the other hand, nearly

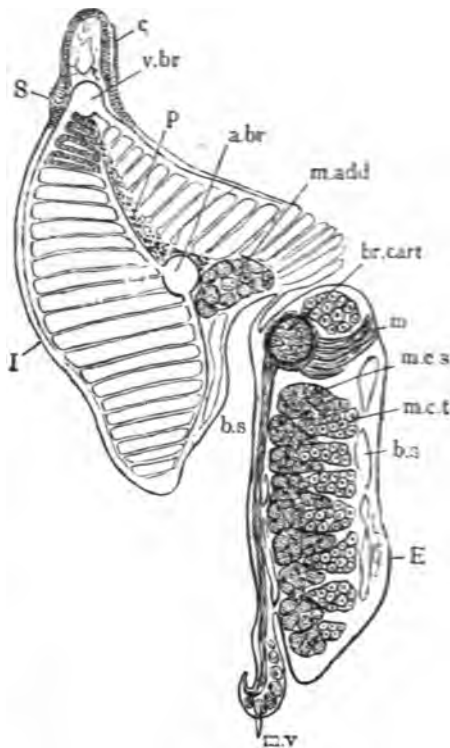


FIG. 2.—Diagram of a longitudinal section through a branchial segment of Ammocetes, at the level of the external branchial opening. E, external; I, internal portion of segment; br. cart., branchial cartilage; m.c.s., striated constrictor muscles; m.c.t., tubular constrictor muscles; m.r., muscles of valve; m., short muscles near branchial opening; m.add., adductor muscles; a.br., branchial artery; v.br., branchial vein; b.s., lacunar blood space; s., sense organ of diaphragm; c., ciliated cells; p., pigment.

in a straight line from its dorsal to its ventral attachments to the branchial cartilage. The tubular constrictor muscle fibres are not attached to the branchial cartilages either dorsally or ventrally, but are continuous dorsally with tendons which pass between the notochord and the dorsal aorta and unite with the

tendons of the tubular constrictors of the other side; ventrally, the tendons pass between the ventral ends of the branchial cartilages and the ventral aorta. Both dorsal and ventral attachments of the tubular muscles are thus internal to the cartilaginous attachments of the striated muscle fibres of the constrictors, whilst at the level of the gill-slits the tubular fibres are external to the striated fibres, owing to the peculiar course of the former. Fig. 4 shows how the tubular fibres cross the striated fibres to reach the skin on the external surface, where some of them are attached, and recross to regain their internal position. In the region of the thyroid the tendons of the tubular muscles are attached to the connective tissue surrounding this organ, as are also a few of the striated constrictor fibres. Each external branchial opening closes by means of a long slender muscle, which passes into a valve-like fold of skin just in front of the opening, and is attached to the branchial cartilage in front of it (fig. 2, *m.v*). Just posterior to each external branchial opening is a short muscle between the cartilage and the skin (fig. 2, *m*). It is attached to the connective tissue beneath the skin, just above and below the posterior side of the opening, and also assists in the closing.

I find, as Dohrn (19) has said, that the area of distribution of the branchial nerve proper, that is, excluding the nerves supplying the epithelial pits, is restricted in the case of the facial to the region of the hyoid arch, and in like manner that of the glosso-pharyngeal and of each division of the vagus is restricted to the following branchial arches.

In *Ammocetes*, the hyoid segment supplied by the facial nerve differs from the succeeding ones in that it is not separated from the velar appendages anterior to it by a cleft opening to the exterior, though Huxley and Dohrn have tried to show that originally a cleft existed here also. The hyoid segment also differs in that it is supported by muco-cartilage, and not by the true cartilage, and bears branchial lamellæ on its posterior surface only. It is further differentiated by the presence of the pseudo-branchial groove (see Pl. III. figs. 1 and 2, Gaskell, 31). This ciliated groove starts from the dorsal side of the branchial chamber, passes round to the ventral side to join its fellow from the opposite side, and runs into the thyroid gland at its orifice

on the floor of the branchial chamber, at the level of the third branchial diaphragm. This segment is usually said to contain no tubular muscle fibres, but I have in one case seen two or three fibres passing ventrally amongst the striated fibres: and there are always some short bundles of tubular fibres, which start dorsally in the same region as the tubular fibres of the velum, but instead of entering the velum, they pass externally, and are attached to the dorsal portions of the muco-cartilage.

The ramus hyoideus of the facial, as it passes beneath the auditory capsule, has a considerable number of small ganglion cells in its course. When the nerve reaches a point about the middle of the auditory capsule, it divides: one portion, the branchial nerve of the hyoid segment, passes abruptly ventralwards; the other portion, the ramus branchialis profundus of Kupffer, retains its position beneath the auditory capsule. I shall deal first with the branchial nerve proper. It passes ventralwards between the muco-cartilage and the striated branchial muscles to a point about the level of the division between the dorsal and ventral masses of body muscles, where it divides, one branch going between the bundles of branchial muscles to their internal side, and the other branch turning directly outwards, passes round the posterior edge of the muco-cartilage, and runs over the top of the ventral mass of body muscles. Here it turns ventralwards, running in the space between the somatic muscles and the laminated layer of the skin; having reached a point a little to one side of the internal median ventral side, it turns sharply forwards, and runs almost to the anterior edge of the lower lip. This is the *ramus mandibularis externus*, and it supplies the most anterior epithelial pit sense organs on the ventral side, gradually diminishing in size as it gives off fibres to them (fig. 1, A. vii.).

That part of the nerve which lies internal to the branchial muscles of the hyoid segment contains the motor fibres to these muscles. One small branch passes straight back to the small group of muscles in the valve (fig. 2, *m.v.*), just in front of the first external branchial opening; the rest of the nerve follows the course of the muscles as they become more ventral, supplying them throughout their course. One small branch, however, separates off early from the motor portion of the nerve,

and follows the course of the pseudo-branchial groove (Pl. II. figs. 1 and 2), passing ventralwards with it. On reaching the orifice of the thyroid, it continues to pass caudalwards on its own side of the gland, sometimes lying close beneath the epithelium lining the ventral surface of the branchial chamber, and sometimes separated from the epithelium by the bands of branchial muscles and their tendinous attachments to the connective tissue surrounding the thyroid. I have traced this nerve to the posterior end of the spirally coiled portion of the thyroid gland, but I have not seen it give off any branches to branchial muscles, nor have I seen any fibres enter the gland itself; but I have seen small branches separate off beneath the epithelium, and I am inclined to consider it as a sensory nerve. Whether sensory or otherwise, its course seems to confirm Gaskell's (30) view that the thyroid gland is all part of the hyoid segment. Julin (17) makes no mention of this nerve; but he finds a branch from the glosso-pharyngeal, and from each of the three anterior branchial divisions of the vagus, passing along the diaphragms of their respective segments into the thyroid.

Dohrn (19) was unable to find any nerve to the thyroid; but, from the method of development of this organ, he thinks it should be innervated by some nerve originating between the facial and the glosso-pharyngeal. I may here say that this is the only nerve I have been able to find that can in any way be said to supply the thyroid, and I have failed to find the nerves Julin describes as passing from the internal branches of the glosso-pharyngeal and the first three divisions of the vagus to the thyroid gland.

The ramus branchialis profundus of Kupffer still remains to be described. It is quite a conspicuous nerve beneath the auditory capsule, between it and the branchial muscles of the hyoid segment. Posterior to the region of these branchial muscles, it is situated just below the internal epithelium of the branchial chamber, close to the jugular vein (Pl. II. fig. 4). It retains this position up to the posterior end of the branchial chamber, except where the tendons of the tubular muscles in each segment pass outwards between it and the epithelium. In each segment a small branch is given off, and innervates the

tubular muscle fibres, and, as far as I have been able to see, it supplies no other tissues. The course of this nerve is so extraordinary that I felt obliged to verify my conclusions most carefully, so I traced the nerve in several specimens, following it through all the branchial segments it supplies, namely, those supplied by the glosso-pharyngeal and the six divisions of the vagus, and always with the same result.

On transformation of *Ammocetes* into *Petromyzon planeri*, it is well known that these peculiar large tubular muscle fibres disappear entirely, being replaced by striated muscles, and it would be most interesting, therefore, to ascertain what is the fate of the nerve which supplies them.

The facts that these muscles have different attachments from the other branchial muscles and a separate nerve supply, and that they disappear on transformation, suggest that they belong to a different category, which can only receive an explanation by reference to some ancestral form.

CONCLUSIONS.

The facial nerve consists of:—

- i. A *motor* portion, supplying the striated muscles of the hyoid segment, including the small muscle in the valve in front of the first external branchial opening.
- ii. An *internal sensory* portion, following the course of the thyroid.
- iii. An *external sensory* portion, supplying epithelial pits belonging to the lateral line system, including—
 - (a) a dorsal branch, the ophthalmicus superficialis;
 - (b) a ventral branch, the mandibularis externus.
- iv. A *motor* branch, the ramus branchialis profundus, supplying the tubular muscles in each branchial segment.

THE GLOSSO-PHARYNGEAL NERVE.

Here, again, we are met with conflicting statements. Julin divides the nerve into a ramus prærematicus and a ramus

and follows the course of the pseudo-branchial groove (Pl. II. figs. 1 and 2), passing ventralwards with it. On reaching the orifice of the thyroid, it continues to pass caudalwards on its own side of the gland, sometimes lying close beneath the epithelium lining the ventral surface of the branchial chamber, and sometimes separated from the epithelium by the bands of branchial muscles and their tendinous attachments to the connective tissue surrounding the thyroid. I have traced this nerve to the posterior end of the spirally coiled portion of the thyroid gland, but I have not seen it give off any branches to branchial muscles, nor have I seen any fibres enter the gland itself; but I have seen small branches separate off beneath the epithelium, and I am inclined to consider it as a sensory nerve. Whether sensory or otherwise, its course seems to confirm Gaskell's (30) view that the thyroid gland is all part of the hyoid segment. Julin (17) makes no mention of this nerve; but he finds a branch from the glosso-pharyngeal, and from each of the three anterior branchial divisions of the vagus, passing along the diaphragms of their respective segments into the thyroid.

Dohrn (19) was unable to find any nerve to the thyroid; but, from the method of development of this organ, he thinks it should be innervated by some nerve originating between the facial and the glosso-pharyngeal. I may here say that this is the only nerve I have been able to find that can in any way be said to supply the thyroid, and I have failed to find the nerves Julin describes as passing from the internal branches of the glosso-pharyngeal and the first three divisions of the vagus to the thyroid gland.

The ramus branchialis profundus of Kupffer still remains to be described. It is quite a conspicuous nerve beneath the auditory capsule, between it and the branchial muscles of the hyoid segment. Posterior to the region of these branchial muscles, it is situated just below the internal epithelium of the branchial chamber, close to the jugular vein (Pl. II. fig. 4). It retains this position up to the posterior end of the branchial chamber, except where the tendons of the tubular muscles in each segment pass outwards between it and the epithelium. In each segment a small branch is given off, and innervates the

tubular muscle fibres, and, as far as I have been able to see, it supplies no other tissues. The course of this nerve is so extraordinary that I felt obliged to verify my conclusions most carefully, so I traced the nerve in several specimens, following it through all the branchial segments it supplies, namely, those supplied by the glosso-pharyngeal and the six divisions of the vagus, and always with the same result.

On transformation of *Ammocoetes* into *Petromyzon planeri*, it is well known that these peculiar large tubular muscle fibres disappear entirely, being replaced by striated muscles, and it would be most interesting, therefore, to ascertain what is the fate of the nerve which supplies them.

The facts that these muscles have different attachments from the other branchial muscles and a separate nerve supply, and that they disappear on transformation, suggest that they belong to a different category, which can only receive an explanation by reference to some ancestral form.

CONCLUSIONS.

The facial nerve consists of:—

- i. A *motor* portion, supplying the striated muscles of the hyoid segment, including the small muscle in the valve in front of the first external branchial opening.
- ii. An *internal sensory* portion, following the course of the thyroid.
- iii. An *external sensory* portion, supplying epithelial pits belonging to the lateral line system, including—
 - (a) a dorsal branch, the ophthalmicus superficialis ;
 - (b) a ventral branch, the mandibularis externus.
- iv. A *motor* branch, the ramus branchialis profundus, supplying the tubular muscles in each branchial segment.

THE GLOSSO-PHARYNGEAL NERVE.

Here, again, we are met with conflicting statements. Julin divides the nerve into a ramus prærematicus and a ramus

posttrematicus ; and, as in the case of the facial, Dohrn disagrees with him. Without entering into the discussion between the two authors concerning the homologies of the gill-clefts in Selachians and those in Cyclostomes, I must say that I entirely agree with Dohrn as to the fallacy of Julin's arguments. Julin calls the main part of his branchial nerve the ramus prætrematicus, and describes a slender branch passing beneath the second gill-cleft, which "se perd en arrière de ce canal, dans la lame branchiale III." I have not been able to find such a branch, and consider, with Dohrn, that the main part of the nerve supplying the region of the first true branchial arch should be called the ramus posttrematicus ; and that, therefore, the sensory ramus prætrematicus passing to the posterior side of the hyoid arch is absent. A ramus prætrematicus is always described in Petromyzon, and it is quite possible that this branch develops on transformation. It is interesting to note that Froriep (14) and Beard (15, p. 107) mention that the prætrematic or pre-branchial nerve, as Beard calls it, develops in elasmobranchs at a later stage than the rest of the branchial nerve.

The area of distribution of the glosso-pharyngeal in *Ammocoetes* is restricted, therefore, to the region of the first true branchial arch,—that is, to the branchial segment contained between the first and second branchial openings (Pl. II. fig. 1),—always excepting the external branches to the sense organs of the lateral line system, which, as we shall see, have an extension forwards, as in the case of the facial.

On leaving the cranium, the roots of the glosso-pharyngeal enter its ganglion. Two nerves leave the ganglion—a dorsal and a ventral nerve. The dorsal nerve passes outwards to the external side of the auditory capsule, where it runs forwards between the dorsal and ventral portions of the first myotomes, close to the ramus recurrens facialis, with which it might easily be confused. It passes to the skin, and supplies the epithelial pits forming the posterior part of the row on the dorsal surface of the head, continuous with those supplied by the ramus ophthalmicus superficialis (fig. 1, B. ix.).

The ventral nerve of the glosso-pharyngeal runs ventrally

from the ganglion, and soon divides into two branches. One of these is the sensory branch, which passes internally, running in the septum of one of the branchial folds to the diaphragm of the first complete branchial segment. On reaching the diaphragm, the nerve turns and runs dorso-ventrally in the connective tissue, close to the afferent branchial vessel in the tip of the diaphragm, and supplies the sense organs situated on the posterior border of the same. I have failed to find the branch of this nerve which Julin describes as going to the thyroid gland. The other branch of the glosso-pharyngeal runs internal to the branchial cartilage, and supplies the striated muscles of this segment, including the small muscle just posterior to the first external branchial opening and the muscles in the valve anterior to the second external branchial opening, both of which muscles are attached to the branchial cartilage. At a point somewhat ventral to the external branchial openings a considerable branch leaves the motor portion of the glosso-pharyngeal and passes outwards, just in front of the cartilage; it makes its way through the upper part of the ventral mass of longitudinal body muscles; and on reaching their external side, turns sharply, and runs ventralwards in the space between the muscles and the skin. This nerve, like the *mandibularis externus* of the facial, runs forwards somewhat to one side of the median ventral line, and supplies the four or five ventral epithelial pits posterior to those supplied by the latter (fig. 1, A. ix.). The pits supplied by this nerve vary in different specimens: for instance, in one specimen the nerve branched off at a higher level than usual, and passed round the top of the ventral longitudinal muscles, and supplied epithelial pits arranged in a row between the level of the branchial openings and the line of pits along the ventral side of the body; that is to say, there was a continuous row of pits from the point where the ventral branch of the glosso-pharyngeal came to the surface, to where the nerve ended on the ventral surface. In another specimen, a small branch was given off as soon as the nerve came to the surface, and supplied a row of five pits just ventral to the first external branchial opening.

We see, then, that the glosso-pharyngeal, like the facial, consists of—

- i. A *motor* portion supplying the striated muscles.
- ii. An *internal sensory* portion to the sense organs on the diaphragm.
- iii. An *external sensory* portion supplying sense organs of the lateral line system, including—
 - (a) a dorsal branch;
 - (b) a ventral branch.

The tubular muscles of the segment are, as we have seen, provided for by the ramus branchialis profundus of the facial.

THE VAGUS NERVE.

The vagus consists of two separate portions, each with its separate ganglion, the *ramus lateralis*, which unites with the ramus recurrens of the facial to form the lateral line nerve, and the *ramus pneumo-gastricus*, which gives rise to the six branchial nerves. The ganglion of the pneumo-gastric is situated behind the auditory capsule, dorsal to the ganglion of the glosso-pharyngeal, as Ahlborn (13) has described. On the course of the nerve are found six small ganglia, which have been called 'epibranchial ganglia,' and just posterior to each of these ganglia passes off the branchial nerve. The first five branchial divisions of the vagus behave in exactly the same way in relation to their respective segments, and it is most interesting to find that each one gives off branches corresponding to those already described in the glosso-pharyngeal and in the facial (Pl. II. fig. 1, x^1-x^2). A very small nerve leaves the epibranchial ganglion in each segment, and instead of passing internal to the cartilage with the rest of the branchial nerve, it remains external to it. It passes ventralwards just internal to the dorsal longitudinal body muscles, and runs round the ventral end of the latter to the external side, where it supplies an epithelial pit in the skin just above the external branchial opening. The only reference to these nerves in *Ammocoetes* that I have been able to find is in Dohrn's (19) work, where, in a larva of ten days old, speaking of the development of the sense organs of the lateral line system, he says: "Dabei ergibt sich zunächst das wichtige Resultat, dass über jeder Kiemenspalte gleichfalls eine solche Rosette am ectoderm gefunden wird, und dass sie benachbart

den Ganglien liegt, aus denen die Kiemennerven entstehen, also in der Nähe der Glossopharyngeus—und sämtlicher Vagus Ganglien. Ich habe schon früher (xii Studie, p. 334) Ausläufer von diesen Ganglien an die Haut beschrieben; jetzt kann ich diese Angabe durch den Nachweis der dazu gehörigen Sinnesorgananlagen vervollständigen." The nerve is extremely small, and I could not in all cases trace it further, but in most segments it turns dorsalwards, and runs to the epithelial pit considerably above the level of the branchial openings. I feel little doubt that this corresponds to the dorsal branch described by van Wijhe (11) and Beard (15) in embryo Elasmobranchs, and by Froiep (14) in Mammals, but which has no representative in the adult animals. This nerve, as they describe it, develops in connection with a thickening of the epidermis, just as it does in *Ammocetes*.

The main part of the branchial nerve, after leaving the vagus trunk, passes internal to the branchial cartilage, and after running ventralwards a short distance, divides. A small group of ganglion cells is found just before the nerve divides, and isolated ganglion cells occur on the course of the branchial nerve. The first branch which leaves the branchial nerve passes internally in the septum of the branchial folds to reach the diaphragm, where it turns abruptly, and runs dorso-ventrally along the top of the diaphragm, and supplies the sense organs on its posterior surface. These internal branches of the glosso-pharyngeal and vagus are largely sensory, supplying the sense organs and the general cutaneous surface of the diaphragm, but it is possible that they may also supply the efferent branchial vessels which run along the internal tip of the diaphragm to join the dorsal aorta. I have failed to find the branch from the nerve which Julin (17) describes in the three anterior branchial divisions of the vagus as running down the diaphragm into the thyroid gland. As in the case of the glosso-pharyngeal, the motor portion of the branchial nerve follows the course of the cartilage, and gives off branches to the striated muscle of the segment. When it has reached a level considerably ventral to the external branchial opening, it gives off a branch which passes round in front of the cartilage and runs outwards, making its way through the ventral longitudinal body muscles; on reaching their external

surface it turns ventralwards, running between the muscles and the skin. At a point a little to one side of the median ventral line it turns and runs forwards, and innervates the epithelial pits continuous with those supplied by the ventral branch of the glosso-pharyngeal and of the facial.

I may here mention that the two rows of epithelial pits on the ventral side of the body are not parallel, but they follow the outline of the ventral pieces of the cartilaginous branchial basket, which in the region of the thyroid gland are some distance apart, whilst behind this region they are quite close together in the median ventral line. Each branchial division of the vagus therefore consists of—

- i. A *motor* portion supplying the striated branchial muscles.
- ii. An *internal sensory* portion to the sense organs on the diaphragm.
- iii. An *external sensory* portion supplying sense organs of the lateral line system, including—
 - (a) a dorsal branch ;
 - (b) a ventral branch.

The tubular muscles are supplied by the ramus branchialis profundus of the facial.

The sixth branchial nerve is different from the others, as the segment it supplies is not a typical branchial segment, but forms the posterior wall of the branchial chamber, and bears branchial folds on its anterior surface only. This segment contains the posterior branchial cartilage and the striated and tubular branchial muscles corresponding to those in the typical segments, but I am not prepared to say where its exact posterior limit is. The sixth branchial nerve has the same divisions as the others, the motor branches innervating the heart and the narrow foregut which opens on the dorsal side of the posterior end of the branchial chamber (Pl. II. fig 1, x^o).

The lateral line nerve formed by the union of the ramus recurrens of the facial and the ramus lateralis of the vagus (Pl. II. figs. 1 and 2) passes back from behind the auditory capsule to the end of the tail. There seems no doubt, from its method of development in the embryo, according to Dohrn (19), that it

supplies the epithelial pits on the dorsal side of the body: but, so far, I have not seen any description of branches passing from the nerve to the pits in the full-grown *Ammocetes*. I have only studied the branchial region at present, and have failed to find any branches passing off from the lateral line nerve; but as I have shown that the pits on the dorsal side of the body in the branchial region are supplied by dorsal branches of the branchial nerves, it is quite possible the lateral line nerve does not give off any branches in this region.

It is clear from the above description that the sense organs of the lateral line system are innervated by the facial, the glosso-pharyngeal, and the vagus, and not by the trigeminal, which is in harmony with all the more recent researches on this subject. I may therefore add one more class of animals to the list given by Cole (29) to which this statement applies:—

1. Cyclostomata (present communication).
2. Holocephali (Cole) (39).
3. Elasmobranchii (Ewart) (23).
4. Teleostei (Pollard—Siluroids, *e.g.*, *Clarias* and *Auchenaspis*) (25).
5. Ganoidei (Allis) (20).
6. Dipnoi (Pinkus) (27).
7. Amphibia (Strong) (28).

That the glosso-pharyngeal innervates a portion of the lateral line system has been shown in Holocephali, in Elasmobranchii, in Teleostei, and in Ganoidei; yet Cole (29) treats this fact as an exception, which may be explained away by future researches. In *Ammocetes*, however, as shown in fig. 1, the glosso-pharyngeal bears as important a part in the innervation of the lateral line organs as does the facial, having its dorsal and ventral branch corresponding to the ramus ophthalmicus superficialis and the ramus mandibularis externus respectively.

The study of this primitive form brings to light yet another point, which is equally important and striking. In all the other classes of animals mentioned the lateral line nerve is the only branch of the vagus which innervates sense organs, whilst in *Ammocetes* each branchial division of the vagus has its dorsal and its ventral branch corresponding to those in the facial and

in the glosso-pharyngeal, and the lateral line nerve itself innervates sense organs posterior to the branchial region only.

The conclusion I am led to, therefore, from the study of *Ammocetes*, is in direct opposition to the tendency expressed by Cole (29), which is to dissociate the lateral line nerves into a separate system from the branchial nerves. I do not mean to express any doubt as to their separate internal destination in the brain; but as far as their peripheral distribution is concerned, they form an essential component of each of the branchial nerves,—that is to say, of the facial, of the glosso-pharyngeal, and of each of the six branchial divisions of the vagus.

NOTE.—This paper would be incomplete without some mention of the connections said by Ransom and Thompson (16) to exist between the dorsal roots of the spinal nerves and the vagus trunk, and by Julin (17) between the ventral spinal roots and the vagus. I have followed the nerves most carefully and seen the spinal nerves passing to the vagus, but in no case have I found them uniting with the vagus to be distributed to the branchial segments.

I have also satisfied myself that Kupffer's (26) *ramus recurrens vagi* (p. 62) has, in fact, no connection with the vagus, though it apparently forms part of the vagus trunk. The large fibres which Kupffer describes as passing off from the vagus at the posterior end of the branchial region and running ventrally to the internal surface of the ventral longitudinal body muscles, and so forwards to the anterior limits of these muscles, are portions of the three or four most anterior ventral spinal roots, and can be distinguished from the vagus nerve with the greatest ease, on account of their size. Not one of these large fibres leaves the brain with the vagus roots, or passes with the branchial nerves to the branchial segments; they belong entirely to the ventral somatic muscles.

SUMMARY.

1. Each branchial nerve is entirely confined to its own segment as far as the motor and general sensory nerves are concerned, and is not divided into a *ramus prætrematicus* and a *ramus posttrematicus*.

2. Each branchial nerve consists of—

- (1) Motor nerves to the striated muscles of a segment.
- (2) Sensory nerves to the diaphragm.
- (3) Dorsal and ventral nerves to sense organs of the lateral line system.

3. The facial nerve has all the component parts of a typical branchial nerve, and belongs, therefore, to the glosso-pharyngeal and vagus group of cranial nerves, and not to the trigeminal group.

4. The thyroid gland is innervated by a branch of the facial nerve, and belongs, therefore, to the hyoid segment.

5. The facial nerve gives off a branch which supplies the tubular muscles in all the branchial segments.

6. The sense organs of the lateral line system on the head and branchial region of the body are innervated by dorsal and ventral branches of the facial, the glosso-pharyngeal, and the six branchial divisions of the vagus.

7. The lateral line sense organs posterior to the branchial region of the body are innervated by the lateral line branch of the vagus.

EXPLANATION OF PLATE II.

Fig. 1. Diagram representing the branchial region of *Ammocetes* and the distribution of the branchial nerves. Nerves coloured *yellow* are external sensory nerves to the sense organs of the lateral line system; nerves coloured *blue* are motor; and nerves coloured *red* are the internal sensory nerves to the diaphragms.

VII. Facial. *R. op. s. vii.*, ramus ophthalmicus superficialis. *R. M. ex. vii.*, ramus mandibularis externus. *n. H. vii.*, ramus hyoideus. *n. Thy. vii.*, thyroid nerve.

IX. Glosso-pharyngeal.

X¹-X⁶. Branchial divisions of vagus. *Xn.*, lateral line nerve. *N.*, external nasal opening. *E.*, eye. *A.*, auditory capsule. *T.*, tentacles. *Vel.*, velum. *Thyr. gl.*, thyroid gland. *L.*, liver. *b.d.*, bile-duct. *f.g.*, foregut.

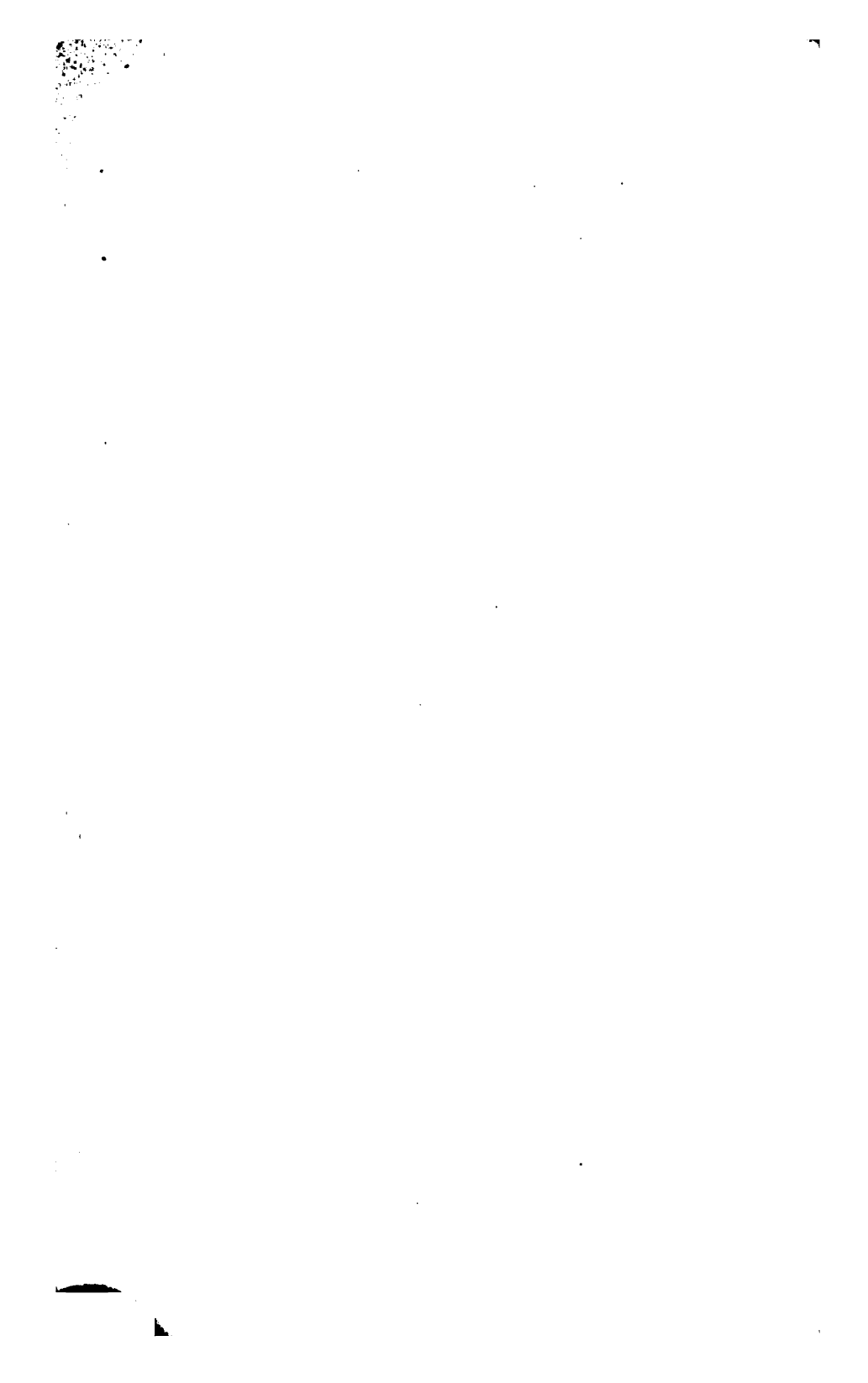
Fig. 2. Diagram showing VII. facial nerve only. Colours as in fig. 1. *Oph. sup.*, ophthalmicus superficialis. *M. ext.*, mandibularis externus. *n. rec. vii.*, ramus recurrens. *n. lat. vii. and x.*, lateral line nerve. *n. Hyoid.*, ramus hyoideus. *n. Thy.*, thyroid nerve. *Br. prof.*, ramus branchialis profundus. *x.*, ganglion of lateral line, branch of vagus.

Fig. 3. Diagram showing IX., glosso-pharyngeal nerve only. Colours as in fig. 1.

Fig. 4. Diagram constructed from a series of transverse sections through a branchial segment, showing the arrangement and relative positions of the cartilage, muscles, nerves, and blood-vessels. Colours of nerves as in Fig. 1. *Br. cart.*, branchial cartilage. *M. con. str.*, striated constrictor muscles. *M. con. tub.*, tubular constrictor muscles. *M. add.*, adductor muscle of diaphragm. *D.A.*, dorsal aorta. *V.A.*, ventral aorta. *S.*, sense organs on diaphragm. *n. lat.*, lateral line nerve. *X.*, epibranchial ganglia of vagus. *r. br.*, prof. vii., ramus branchialis profundus of facial. *J.v.*, jugular vein. *Ep. pit.*, epithelial pit. *l.s.*, lacunar blood-space.

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ON THE ORIGIN OF VERTEBRATES, DEDUCED FROM
THE STUDY OF AMMOCETES. By WALTER H.
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ology ; Fellow of Trinity Hall, Cambridge.* (PLATE III.)

PART III.—ON THE ORIGIN OF THE BRANCHIAL
SEGMENTATION.

IN this part of my paper, as in the previous parts, it will conduce to clearness of conception if I commence by giving a historical sketch of the views which have been held upon the segmentation of the head in vertebrates, and for this purpose I cannot do better than follow the admirable and lucid account given by Rabl¹ at the meeting of the German Anatomical Society at Vienna in 1892.

The first attempt was made by Goëthe and Oken ; they considered that the cranial skeleton was composed of a series of vertebræ ; but as early as 1842 Vogt pointed out that only the occipital segments could be reduced to vertebræ. In 1869, Huxley showed that vertebræ were insufficient to explain the head segmentation, and that nerves must especially be considered. The olfactory and optic nerves were parts of the brain, not true segmental nerves ; the rest of the cranial nerves were segmental, with especial reference to branchial arches and clefts, the facial, glosso-pharyngeal, and separate vagus branches supplying the walls of the various branchial pouches. In a similar manner, the supra-œsophageal and infra-œsophageal maxillary branches of the trigeminal were arranged round the mouth and the inner and outer twigs of the 1st (ophthalmic) branch of the trigeminal on each side of the orbito-nasal cleft, the trabecular and the supra-maxillary being the arches on each side of this cleft. Thus Huxley considered that there was evidence of a series of pairs of ventral arches belonging to the skull, viz., the trabecular and maxillary in front of mouth, the mandibular, hyoid, and branchial arches behind, and that the Vth, VIIth, IXth, and Xth nerves were segmental in relation to these arches and clefts. Gegenbaur, in 1871 and 1872, considered that the branchial arches represented the lower arches of cranial vertebra, therefore corresponded to lower arches in the spinal region, *i.e.*, the skull was composed of as many vertebræ as branchial arches. These vertebræ were confined to the notochordal part of the skull : the prechordal part has arisen secondarily from the vertebral part ; the number of vertebræ are at least 9, possibly more. The nerves which could be homologised with

¹ *Anat. Anzeiger*, 1892, p. 104.

spinal nerves were divisible into two great groups—(1) the trigeminal group, which included the eye-muscle nerves, the facial, and its dorsal branch, the auditory; (2) the vagus group, which included the glosso-pharyngeal and vagus.

Such was the outcome of the purely comparative anatomical work of Huxley and Gegenbaur,—work that has profoundly influenced all the views of segmentation up to the present day.

Now came the investigations of the embryologists, of which I will take, in the first instance, Balfour, whose observations on the embryology of the Selachians led him to the conclusion that besides the evidence of segmentation to be found in the cranial nerves and in the branchial clefts, further evidence was given by the existence of head cavities, the walls of which formed muscles just as in the spinal region. He came to the conclusion that the 1st head cavity belonged to one or more preoral segments, of which the nerves were the oculomotor, trochlearis, and possibly abducens; while there were seven postoral segments, each with its head cavity and its visceral arch, of which the trigeminal, facial, glosso-pharyngeal, and the four parts of the vagus were the respective nerves.

Marshall, in 1882, considered that the head segments were all originally respiratory, and that all the segmental nerves are arranged uniformly with respect to a series of gill clefts which have become modified anteriorly, and have been lost to a certain extent posteriorly. He included the olfactory nerves among the segmental nerves, and looked upon the olfactory pit, the orbito-nasal lacrymal duct, the mouth, and the spiracle as all modified gill slits, so that he reckoned 3 preoral and oral segments belonging to the 1st, IIIrd, IVth, and Vth nerves, and 8 postoral segments belonging respectively to the VIIth and VIth nerves, to the IXth nerve, and 6 segments belonging to the Xth nerve. He pointed out that muscles supplied by the oculomotor develop from the outer wall of the 1st head cavity; not, however, the obliquus superior and rectus externus, the latter probably from the walls of the 3rd cavity.

In the same year, 1882, came v. Wijhe's well-known paper, in which he showed that the mesoderm of the head in the Selachian divided into two sets of segments, dorsal and ventral; that the dorsal segments were continuous with the body somites, and that the ventral segments formed the lateral plates of mesoblast between each of the visceral and branchial pouches. He concluded that the dorsal somites were originally 9 in number, that each was supplied with a ventral nerve root, in the same way as the somites in the trunk, and to each one there corresponded a visceral pouch, the walls of which were supplied with the corresponding dorsal nerve root; of these 9 segments, the ventral nerve roots of the 1st 3 segments were respectively the oculomotor, trochlearis, and abducens nerves. The next 3 segments possessed no definable ventral root or muscles, and the 7th, 8th, and 9th segments possessed as ventral roots the hypoglossus nerve, with its muscular supply. The corresponding dorsal nerve roots were the trigeminal, facial, auditory, glosso-pharyngeal, and vagus nerves, the difference between cranial and spinal dorsal roots being that the former

contain motor fibres. He says that every nerve to a visceral arch arises after the fashion of a spinal dorsal root, dividing into a *R. dorsalis* and a *R. ventralis*, each of which may be ganglionated. The *R. ventralis* divides into two main branches, a *R. posttrematicus* and a *R. pharyngeus*, the latter of which sends off a *R. pretrematicus*. The vagus is a complex nerve, each portion of which possesses a separate ganglion, which amalgamates with the epidermis of the posterior wall of the gill cleft anterior to it. From this place the nerve forms a pharyngeal and pretrematic branch.

Ahlborn, in 1884, drew a sharp distinction between the segments of the mesoderm and those of the eudoderm. The former segmentation he called mesomeric, the latter branchiomic. He considered the two segmentations independent, and concluded that the branchiomic was secondary to the mesomeric, and therefore not of segmental value. As to the segments of the mesoderm in the head, the three hindmost or occipital in Petromyzontidæ remain permanently, and correspond to the 3 last segments in the selachian head. Of the anterior mesoderm segments, he considers there were originally 6, and that there are 6 typical eye-muscles in all Craniota, which have been compressed into 3 segments, as in Selachia.

Froriep showed in sheep embryos and in chicks that the hypoglossus nerve belonged to 3 proto-vertebræ posterior to the vagus region, which were true spinal segments. He therefore modified Gegenbaur's conceptions to this extent: that portion of the skull designated by Gegenbaur as vertebral must be divided into two parts, a hind or occipital region, which is clearly composed of modified vertebræ, and is the region of the hypoglossus, and a front region, extending from the oculomotor to the accessorius nerves, which is characterised segmentally by the formation of branchial arches, but in which there is no evidence that proto-vertebræ were ever formed. He therefore divides the head skeleton into three parts:—

1. Gegenbaur's evertbral part—the region of the olfactory and optic nerves—which cannot be referred to any metameric segmentation.
2. The pseudo-vertebral, prespinal, or branchial part, clearly segmented from consideration of the nerves and branchial arches, but not referable to proto-vertebræ—the region of the trigeminal and vagus nerves.
3. The vertebral spinal part—the region of the hypoglossus.

He further showed that the ganglia of the specially branchial nerves, the facial, glosso-pharyngeal, and vagus, are at one stage in connection with the epidermis, so that these parts of the epidermis represent sense organs which do not develop; these organs probably belonged to the lateral line system. As the connection takes place at the dorsal edge of the gill slits, they may also be called rudimentary branchial sense organs.

Since this paper of Froriep's, it has been generally recognised, and Gegenbaur has accepted Froriep's view, that the three hindmost metameres which distinctly show the characteristics of vertebræ belong to the spinal and not to the cranial region, so that the meta-

meric segmentation of the cranial region proper has become more and more associated with the branchial segmentation. Froriep's discovery of the rudimentary branchial sense organs as a factor in the segmentation question has led Beard to the conclusion that the olfactory and auditory organs represent in a permanent form two of these rudimentary branchial sense organs. He therefore includes both the olfactory and auditory nerves in his list of cranial segmental nerves, and makes 11 cranial branchial segments in front of the spinal segments represented by the hypoglossal.

A still larger number of cranial segments are supposed to exist, according to the researches of Dohrn and Killian, in the embryos of *Torpedo ocellata*. The former, holding to the view that vertebrates arose from annelids, considered that the head was formed of a series of metameres, to each one of which a mesoderm segment, a gill arch, a gill cleft, a segmental nerve and vessel belonged; he found in the front head region of a *Torpedo* embryo corresponding to v. Wijhe's first 4 somites, no less than 12-15 mesoderm segments, and concluded, therefore, that the eye-muscle nerves, especially the oculomotor, represented many segmental nerves, and were not the nerves of single segments; so also the inferior maxillary part of the trigeminal and the hyoid nerve of the facial are probably not single nerves, but a fusion of several. Killian comes to much the same conclusion as Dohrn, for he finds 17-18 separate mesoderm segments in the head, of which 12 belong to the trigeminal and facial region.

Rabl, in summing up the whole history, so far, considers that there is no definite evidence to be obtained of the number of segments in the front part of the head—i.e., the part in front of the occipital segments—from the consideration of the segmentation of the mesoderm. He thinks there is no evidence of segmental arrangement of the mesoderm there; at all events, anything of the kind is very different from what takes place in the trunk. He also thinks we know as little about the number of segmental nerves as about the number of somites in the head.

Since Rabl's paper, a number of papers have appeared, especially from America, dealing with yet another criterion of the original segmentation of the head, viz., a series of divisions of the central nervous system itself, which are seen at a very early stage of development, and are called neuromeres; the divisions in the cranial region being known as encephalomeres, and those of the spinal region as myomeres. Locy's paper¹ has especially brought these divisions into prominence as a factor in the question of segmentation. They are essentially segments of the epiblast and not of the mesoblast; they are conspicuous in very early stages, and appear to be in relation with the cranial nerves, according to Locy. He recognises in *Squalus acanthias*, in front of the spino-occipital region, 14 pairs of such encephalomeres and a median unsegmented tip, which may represent one more pair fused in the middle line, making at least 15. He distributes these 15 segments as follows:—fore-brain 3, and unseg-

¹ *Jour. of Morphol.*, vol. xi., 1895, p. 497.

mented tip, mid-brain 2, and hind-brain 9; the relation of the nerves to these encephalomeres being as follows:—

Fore-brain,	1 olfactory.	2 optic.	3 pineal.
Mid-brain,	4 oculomotor.	5 trochlearis.	
Hind-brain,	6 trigeminal.	7 trigeminal.	8 unknown. 9 facial.
	10 auditory.	11 glosso-pharyngeal.	
	12, 13, 14 vagus.		

According to him, this primitive segmentation can be traced into the smaller number of segments, as given by v. Wijhe, with the growth of the animal.

Again, Kupffer, in his recent papers on the embryology of *Amocoetes*, asserts that especial information as to the number of primitive segments is afforded by the appearance in the early stages of a series of epibranchial ganglia in connection with the cranial nerves, which remain permanently in the case of the vagus nerves, but disappear in the case of the pro-otic nerves. He considers that the evidence points to the number of segments in the mid- and hind-brain region, as being primitively 15, viz., 6 segments belonging to the trigeminus and abducens group, 3 segments belonging respectively to the facial, auditory, and glosso-pharyngeal, and 6 to the vagus.

The consideration of this historical retrospect brings out prominently certain points of great value in attempting to judge of the present position of the question.

1. It is clear that the original attempt to reduce the head region to a series of spinal segments, permeates and dominates the work and conceptions of all the investigators, from the earliest time until now, so that the cranial nerves are still divided into ventral and dorsal roots.

2. It is equally clear that the branchial segmentation, which is not represented in the spinal region, has been much more clearly shown and proved in the cranial region than the mesomeric or somatic segmentation, which is supposed to be comparable to the spinal segmentation.

3. More and more prominence has been given to the division of the cranial segmentation into two regions—a prootic and an opisthotic region, of which the segmentation of the latter is essentially dependent on the presence of branchial segments, while that of the former may be something different, the presence of branchial segments being surmised, not proved.

4. Spinal vertebral segments have become part and parcel of the head region in so far as the spino-occipital segments are concerned.

5. The tendency is distinctly towards an increase in the number of segments which form the head, especially in the prootic region,—an increase which, if Locy's encephalomeres are to be accepted, is conspicuous in the earliest stage, and gives way to the more diminished number by the amalgamation of primitive separate segments to form the segments of v. Wijhe and the neuromeres of Neal,¹ etc.

Thus we see that, if we consider only the segmental cranial nerves proper, leaving out the optic, olfactory, and pineal nerves with the segments of the fore-brain; and further, if we choose the most fixed point possible posteriorly, viz., the glosso-pharyngeal nerve and segment, the different observers place the glosso-pharyngeal segment as follows:—Gegenbaur, Balfour, Marshall, 4th; v. Wijhe, 5th; Beard, 6th; Locy, 8th; and Kupffer, 9th.

In my opinion, the real difficulty of coming to a satisfactory conclusion upon the cranial segmentation proper, i.e., the segmentation of the parts anterior to the occipital or included spinal region, is on account of the bias in favour of their being modified spinal segments, each with its segmental nerve built up of dorsal and ventral roots; whereas if, as pointed out in Part I. of this series of papers, the cranial region is the older, and the spinal derived from it, then the older plan on which the cranial nerves are formed may be different from that of the spinal and the ventral and dorsal root arrangement a derivation from the original plan, and not *vice versa*. On this ground, it is advisable to consider the plan upon which the cranial nerves are built up, apart from any preconceived notions.

In the markedly segmented animals of the invertebrate group, viz., the Appendiculata, the segmentation of the nervous system is well marked in the central nervous system itself, and the ultimate appeal as to the segmental position of any nerve, i.e., of any motor nerve, is not the place of its apparent exit from the central nervous system, but the position in that system of the group of cells constituting its centre or nucleus of origin. So

¹ Neal, "The Segmentation of the Nervous System in *Squalus acanthias*," *Bulletin of Museum of Comparative Zool.*, Harvard, vol. xxxi. p. 147, 1898.

The literature referring to neuromeres is given in this paper: the author is not in complete agreement with Locy's observations.

also, as I have previously urged, the point of vital importance in the estimation of the segmental value of the vertebrate cranial motor nerves must be the arrangement of their central nuclei in the hind- and mid-brain.

One of the most striking characteristics of the cranial nerves, as distinguished from the spinal, is the manner in which the nuclei of origin of the motor nerves form distinct groups separate from each other. Such groups have long been known to fall into two distinct lines, of which the hypoglossal, abducens, trochlear, and oculomotor nuclei form one group, and the motor nucleus of the trigeminal, the nucleus of the facial, the nucleus ambiguus, and the nucleus of the spinal accessory form another. The importance of recognising and taking into consideration these two separate anterior and lateral groups of cranial nuclei in any question of segmentation of the head was put forward by Hill¹ in 1885; and in 1886 I published my paper,² in which I pointed out that the cranial nerves were built up of the same elements as the spinal, but that those elements were arranged differently, not being separated into a dual arrangement of motor and sensory roots, but into a triple arrangement of roots, of which the middle or lateral root was mixed, containing both motor and sensory elements. Further, this triple arrangement was again divisible into a dual arrangement, corresponding, not with a division into afferent and efferent components, but into a division corresponding with the branchiomic and mesomic segmentation; and wishing to avoid the term 'branchial' in regions where there was no evidence that branchiæ had ever existed, I made use of the terms 'splanchnic' and 'somatic' to represent these two segmentations. I therefore came to the conclusion that the somatic segments were characterised by the possession of nerves which, like the spinal, were divided into ventral motor and dorsal sensory roots, the sensory part of the Vth nerve, with its so-called ascending root, being the collected dorsal somatic roots, while the IIIrd, IVth, Vth, and XIIth nerves represented the ventral somatic roots; subsequently, I gave reasons for supposing that originally

¹ Hill, *The Plan of the Central Nervous System*, Cambridge, 1885.

² Gaskell, "On the Structure, Distribution, and Function of the Visceral and Vascular Nerves," *Jour. of Physiol.*, vol. vii. p. 1, 1886.

the eye-muscle nerves were not purely motor, but contained sensory elements of unknown signification. The nuclei of the hypoglossal, abducens, trochlearis, and oculomotor were to be looked upon as the continuation of the somatic motor centres of the anterior horn.

On the other hand, the splanchnic segments were innervated each by a single lateral nerve, mixed with respect to its sensory and motor elements, of which the latter arose from a well-defined series of lateral centres in the brain and cervical cord, viz., the motor nuclei of the accessory, vagus, glosso-pharyngeal, facial, and trigeminal nerves. Two years later, in 1888, His¹ pointed out the same thing, drawing attention to the significance of this dual arrangement of the motor nuclei of the cranial nerves, just as Hill and I had previously done. His never mentioned either Hill's paper or mine, in consequence of which His's paper alone is frequently referred to in morphological journals, although it was published two years after mine and three after Hill's.

This manner of looking upon the cranial nerves immediately suggests a reason for the difference between the cranial and spinal nerves, viz., that the spinal arrangement is due to the preponderance there of the mesomeric or somatic segmentation; while in the cranial arrangement, though a somatic segmentation is still represented, it is overshadowed and dwarfed by the preponderating branchiomic or splanchnic segmentation.

Further, a possible clue is given why the cranial vertebrate segmental nerves should be triple in character, and supply two segmentations, when we consider the nature and the distribution of the nerves which supply the prosomatic and mesosomatic segments of Arthropoda, especially of *Limulus* and its allies. The observations of Milne Edwards,² that each prosomatic segment is supplied by three nerves, of which one is purely somatic sensory, thus forming the series of epimeral nerves which supply the tergal carapace; another—which is the most conspicuous of the three, and is a mixed nerve, containing both sensory and motor fibres—is a purely appendage nerve, and supplies nothing

¹ His, "Die Morphologische Betrachtung der Kopfnerven," *Archiv f. Anat.*, 1888, p. 379.

² *Anatomie des Limules.*

else except its appendage; the third nerve arises near to, but separately from, the appendage nerve, and is said by Milne Edwards to supply the neighbouring muscles, *i.e.*, body muscles as distinguished from the appendage muscles; he does not say whether such nerve supplies any part of the somatic surface with sensory fibres. In the mesosomatic region the same arrangement exists, so that here, where the appendages carry branchiæ, we have the same arrangement as in the vertebrate branchial region, *viz.*, a series of branchial nerves, which are mixed in character, arising independently of the somatic sensory and motor nerves.

Moreover, just as in the vertebrate central nervous system the centres of origin of the motor nerves of the branchial segmentation are distinct from those of the somatic segmentation, so we find, from the admirable researches of Hardy,¹ that a similar well-marked separation exists between the centres of origin of the motor nerves of the appendages and those of the somatic muscles in the central nervous system of Branchipus and Astacus.

In the first place, he points out that the nervous system of Branchipus is of a very primitive arthropod type; that it is, in fact, as good an example of an ancient type as we are likely to get in the present day, a matter of some importance in connection with my argument, as undoubtedly the arthropod ancestor of the vertebrate, such as I am deducing from the study of Ammocetes, must have been of an ancient type, more nearly connected with the strange forms of the trilobite era than with the crabs and spiders of the present day.

His conclusions with respect to Branchipus may be tabulated as follows:—

1. Each ganglion of the ventral chain is formed mainly for the innervation of the appendages.
2. Each ganglion is divided into an anterior and posterior division, which are connected respectively with the motor and sensory nerves of the appendages.
3. The motor nerves of the appendages arise as well-defined axis-cylinder processes of nerve cells, which are arranged in well-defined groups in the anterior division of the ganglion.
4. A separate innervation exists for the muscles and sensory

¹ *Phil. Trans.*, 1894, p. 85.

surfaces of the trunk. The trunk muscles consist of long bundles, from which slips pass off to the skin in each segment; they are thus imperfectly segmented. In accordance with this, a diffuse system of nerve fibres passes to them from certain cells on the dorsal surface of each lateral half of the ganglion. These cell groups are therefore very distinct from those which give origin to the motor appendage nerves, and, moreover, are not confined to the ganglion, but extend for some distance into the interganglionic region of the cords.

Hardy's observations, therefore, combined with those of Milne Edwards, lead to the conclusion that in such a primitive arthropod type as my theory postulates, each segment was supplied with somatic sensory and motor nerves, and with a nerve of mixed function, devoted entirely to the innervation of the appendage; that also, in the central nervous system, the motor nerve centres were arranged in accordance with a double set of segmented muscles, viz., well-defined nerve-cell groups, which formed the centres for the motor nerves of the markedly segmented muscles of the appendages, and a system of more diffused cells, less markedly aggregated into distinct groups, which formed the centres for the imperfectly segmented somatic muscles.

Such an arrangement suggests that in the ancient arthropod type a double segmentation existed, viz., a segmentation of the body, and a segmentation due to the appendages. Undoubtedly, originally the segments in each case corresponded absolutely as in Branchipus, and every appendage was attached to a well-defined separate body segment. When, however, we examine such an ancient type as *Limulus* we see that, though the segmentation may be spoken of as twofold, yet the number of segments in the prosomatic and mesosomatic regions are much more clearly marked out by the appendages than by the divisions of the soma; for in the prosomatic region such a fusion of somatic segments to form the tergal prosomatic carapace has taken place that the segments of which it is composed are visible only in the young condition, while in the mesosomatic region the separate somatic segments, though fused to form the mesosomatic carapace, are still indicated by the entapophysial indentations.

It is, then, clear that if the mesosomatic branchial appendages of forms related to *Limulus* were reduced to the branchial portion

of the appendage, and that branchial portion became internal, just as is known to be the case in the scorpion group, we should obtain an animal in which the *mesosomatic region* would be characterised by a segmentation predominantly branchial, which might be termed, as in vertebrates, the branchiomic segmentation, yet showing indications of a corresponding somatic or mesomeric segmentation; and the nerve supply to these segments would consist of—

1. The epimeral purely sensory nerves to the somatic surface, equivalent to the ascending root of the trigeminal.

2. The mixed nerves to the internal branchial segments, equivalent to the vagus, glosso-pharyngeal, and facial.

3. The motor nerves to the somatic muscles, equivalent to the original nerve supply to the somatic muscles belonging to these segments, *i.e.*, to the muscles derived from v. Wijhe's 4th, 5th, and 6th somites.

Further, the centres of origin of these appendage nerves would form centres in the central nervous system separate from the centres of the motor nerves to the somatic muscles, just as the centres of origin of the motor parts of the facial, vagus, and glosso-pharyngeal form groups of cells quite distinct from the centres for the hypoglossal, abducens, trochlear, and oculomotor.

In fact, if the vertebrate branchial nerves are looked upon as the descendants of nerves which originally supplied branchial appendages, then every question connected with the branchial segmentation, with the origin and distribution of these nerves, receives a simple and adequate solution, which, moreover, is in exact harmony with the conclusions arrived at in Parts I. and II. as to the origin of the brain and cranial skeleton respectively. As already stated in my Liverpool address, there is, in my opinion, distinct evidence of the presence of such modified branchial appendages in *Ammocetes*, the nature of which I will now proceed to state.

*The Origin of the Respiratory Mechanism ; the Meaning of the
IXth and Xth Nerve.*

The most conclusive evidence of the value of embryology for the study of evolution is given by the consideration of the

respiratory system in the vertebrates, for by its means it is conclusively proved that all the higher air-breathing vertebrates have arisen from water-breathing, gill-bearing ancestors, so that it is absolutely certain that the original form of respiration was by means of branchiæ after the type of fishes. Again, among the fishes themselves, we find two distinct types of branchial apparatus, viz., that found in the majority of the great fish group, and that which is characteristic of the Cyclostomata, in which the cartilaginous bars supporting the branchiæ are extra-branchial in position. This latter type is universally regarded as the most primitive; so that if we can explain how this very striking and peculiar arrangement of the respiratory apparatus arose, we shall, at the same time, explain the origin of the respiratory mechanism of the whole vertebrate kingdom.

In order to make clear the nature of the branchial segments in *Ammocetes*, I have divided the head part of the animal by means of a longitudinal horizontal section into halves, ventral and dorsal, as shown in the figs. 1 and 2, Pl. III. These figures are each a combination of a section and a solid drawing. The animal was slit open by a longitudinal section in the neighbourhood of the gill slits, and each half was slightly flattened out so as to expose the ventral and dorsal internal surfaces respectively. The structures in the cut surface were drawn from one of a series of horizontal longitudinal sections taken through the head of the animal. These figures show that the head region of *Ammocetes* consists of two chambers, the contents of which are different. In front an oral or stomodæal chamber, which contains the velum and tentacles, is inclosed by the upper and lower lips, and was originally separated by a septum from the larger respiratory chamber which contains the separate pairs of branchiæ. A glance at the two drawings shows clearly that Rathke's¹ original description of this chamber is the natural one, for he at that time, looking upon *Ammocetes branchialis* as a separate species, described the branchial chamber as containing a series of paired gills, with the gill openings between consecutive gills. His branchial unit or gill, therefore, was represented by each of the so-called diaphragms, which on section are seen

¹ Rathke, "Anatomie des Querdors," 1827, *Naturforsch. Gesell. zu Dantz.*, vol. ii.

to be trefoil-shaped, to depend into the respiratory chamber, and to be attached to its wall by a narrow stalk. This view makes the space between the branchiæ, or gill pouch, as it is called in higher fishes, and the gill slits, intersegmental, and the branchial cartilages, muscles, etc., intrasegmental. On the other hand, later observers, realising that *Ammocetes* is the larval form of *Petromyzon*, and desirous to use the same phraseology as for the rest of the fishes, speak of the branchial unit as a gill pouch, the walls of which form branchiæ, so that the gill pouches and gill slits are intrasegmental, while the middle of each diaphragm and each cartilaginous bar is intersegmental. In fig. 1 I give

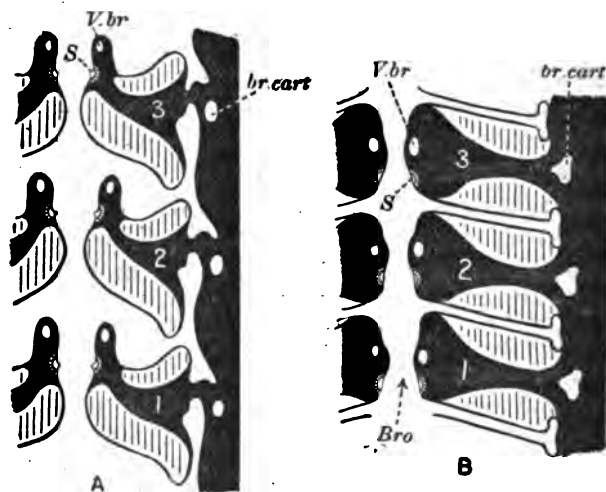


FIG. 1.—Diagram of three branchial segments of *Ammocetes* compared with three branchial segments after transformation, to show how the branchial appendages of *Ammocetes* form the branchial pouches of *Petromyzon*. (After Nestler.) In both figures the branchial cartilages (*br. cart.*), the branchial veins (*V. br.*), and the sense organs (*S.*) are marked out in order to show corresponding points. The muscles, blood spaces, branchial arteries, etc., of each segment are not distinguished, being represented a uniform black. *Bro.*, the bronchus into which each gill pouch opens.

diagrammatic illustrations taken from Nestler's paper¹ to show the striking change which takes place at transformation, A representing three branchial segments of *Ammocetes*, and B the corresponding three segments of *Petromyzon*. The corresponding

¹ *Archiv f. Naturgeschich. Jahrg.* 56, vol. i., 1890, p. 81.

parts in the two diagrams are shown by the cartilages (*Br. cart.*), the sense organs (*S.*), and the branchial veins (*U. Br.*); the corresponding diaphragms are marked by the figures 1, 2, 3 respectively. As is clearly seen, it is perfectly possible in the latter case to describe the respiratory chamber, as Nestler has done, as divided into a series of separate smaller chambers—the gill pouches—by means of a series of diaphragms or branchial bars. The surface of these gill pouches is in part thrown into folds for respiratory purposes, and each gill pouch opens on the one hand into the bronchus (*Bro.*), and on the other, to the exterior by means of the gill slit. The branchial unit or gill is therefore, according to Nestler and other morphologists, in *Petromyzon*, the folded opposed surfaces of two contiguous diaphragms and each one of the diaphragms is intersegmental between two gill pouches.

Nestler then goes on to describe the arrangement in *Ammocetes* in the same terms, although there is no bronchus, no gill pouch, but only an open chamber, into which these gill-bearing diaphragms project, which open chamber serves both for the passage of food and the water of respiration. This is manifestly the wrong way to look at the matter: the adult form is derived from the larval, not *vice versa*; and the transformation process shows exactly how the gills, in Rathke's sense, come together to form the branchial, and so make the gill pouches of *Petromyzon*.

What, then, is the branchial unit in *Ammocetes*? A glance at the figs. 1 and 2, PL III., shows that the respiratory chamber is divided into a series of branchial segments, all exactly alike, except the first and the last. Any one of these is represented in section in fig. 2, and represents a branchial unit in Rathke's view and in mine. Clearly, it may be described as a branchial appendage which projects into an open pharyngeal chamber, so that the series of such appendages divides the chamber into a series of compartments, each of which communicates with the exterior by means of a gill slit, and with each other by means of the open space between opposing appendages. Each of these appendages possesses its own cartilaginous bar (*Br. cart.*), as explained in Part II.; each possesses its own branchial or visceral muscles (coloured light red in figs. 1 and 2, PL III.), separated absolutely from the longitudinal somatic muscles (coloured dark

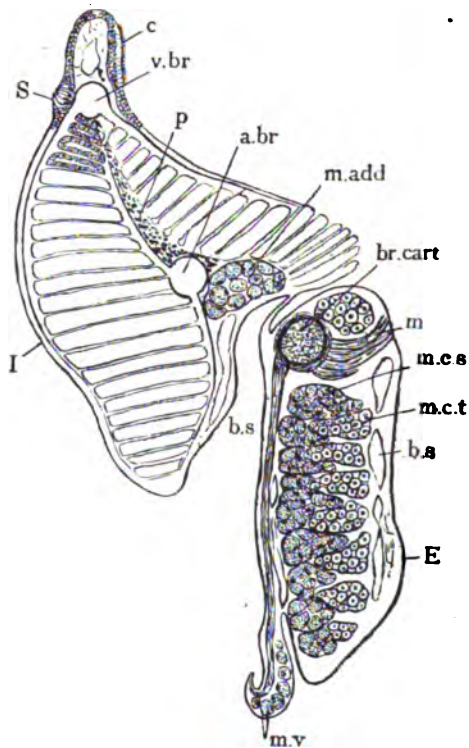


FIG. 2.—Section through branchial appendage of *Ammocetes*. *br. cart.*, branchial cartilage; *v.br.*, branchial vein; *a.br.*, branchial artery; *b.s.*, blood spaces; *p.*, pigment; *S.*, sense organ; *c.*, ciliated band; *E.*, external; *I.*, internal border; *m.add.*, adductor muscle; *m.c.s.*, striated constrictor muscle; *m.c.t.*, tubular constrictor muscle; *m.* and *m.v.*, muscles of valve.

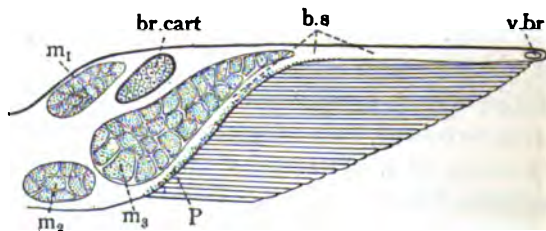


FIG. 3.—Section through branchial appendage of *Limulus*. *br. cart.*, branchial cartilage; *v.br.*, branchial vein; *b.s.*, blood spaces formed by branchial artery; *P.*, pigment; *m₁*, posterior entapophysio-branchial muscle; *m₂*, anterior entapophysio-branchial muscle; *m₃*, external branchial muscle.

red in figs. 1 and 2, Pl. III.) by a space (*Sp.*) containing blood and peculiar fat cells, etc. Each possesses its own afferent branchial blood-vessel from the ventral aorta and its own efferent vessel to the dorsal aorta (fig. 2, *a. br.* and *v. br.*). Each possesses its own segmental nerve, which supplies with motor fibres its own branchial muscles and no others, and with sensory fibres the general surface of each appendage, together with the special sense organs in the shape of the epithelial pits (*S.*, fig. 2) arranged along the free edges of the diaphragms; each of these nerves possesses its own ganglion, the epibranchial ganglion.

The work of Miss Alcock¹ has shown that the segmental branchial nerve supplies absolutely such an appendage or branchial segment, and does not supply any portion of the neighbouring branchial segment; this nerve is that usually called the posttrematic branch; the only branch which can be called pretrematic passes from the epibranchial ganglion to supply the dorsal epithelial pits belonging to the lateral line system. Such a distribution does not indicate that the segmental branchial nerve supplies the two sides of a branchial pouch, and therefore does not tend to support the view that such branchial pouch was the original branchial unit, but, on the contrary, is evidence that the segmental branchial nerve was originally a single nerve, which supplied with both motor and sensory elements the branchial part of an appendage, combined with another purely sensory nerve which belonged to the lateral line system, being entirely devoted to the supply of the epithelial pits on the surface of the skin in the branchial region.

Also, the embryological evidence as to the manner in which the diaphragms are formed seems to me exactly what we should expect to find if they were originally internally situated appendages, for they arise distinctly as buddings or ingrowths into the pharyngeal or respiratory cavity. Thus Shipley says,² "The gill slits appear to me to be the result of the ventral downgrowth of mesoblast taking place only at certain places, these forming the gill bars. Between each downgrowth the hypoblastic lining of the alimentary canal remains in contact with the epiblast; here the gill opening subsequently appears about the twenty-second day."

¹ *This Journal*, vol. xxxiii. p. 131.

² *Quart. Jour. Micr. Sci.*, 1887, p. 24.

There is no evidence whatever that the diaphragms have been formed by the thinning out at intervals of a thick pharyngeal wall, so as to form pouches, with the originally thick wall between, but, on the contrary, a thickening and ingrowth takes place at intervals, and so the diaphragms or branchial appendages are formed. The formation is exactly of the kind that must take place if these diaphragms were originally internally situated appendages.

Embryology further shows that each branchial segment in *Ammocetes*, as in other fishes, possesses its own coelomic cavity. Thus Shipley¹ says, "the mesoblast between the gills arranges itself into head cavities, and the walls of these cavities ultimately form the skeleton of the gill arches." So also in *Limulus*, Kishinouye² describes the formation of a coelomic cavity in every one of the mesosomatic or branchial segments, and states that in *Arachnida* the segmental coelomic cavities extend into the limbs. Both in the vertebrate and in the arthropod, these cavities disappear before the adult condition is reached.

Further, just as in Part II. of this series of papers each of the cartilaginous bars of the branchial appendages of *Limulus* were comparable in structure and position with the branchial cartilaginous bars of *Ammocetes*, so also the rest of the branchial appendage of *Ammocetes* can be compared in its structure and arrangements with the branchial appendage of an ancient form of arthropod, the nearest type of which obtainable at the present day is the branchial appendage of *Limulus*.

The Origin of the Branchial Vascular System, and of the Heart.

A branchial appendage is essentially an appendage whose vascular system is arranged for the special purpose of aerating blood. In the higher vertebrates such a purpose is attained by the pulmonary capillaries. In *Limulus*, by the division of the posterior surface of the basal part of the appendage into thin lamellar plates, the interior of each of which is filled with blood, the two surfaces of each lamella are kept parallel to each other by means of fibrous or cellular strands forming

¹ *Op. cit.*

² *Journ. of College of Science*, Tokio, vol. v., 1891, p. 53.

little pillars at intervals, called by Macleod *colonnettes*.¹ Precisely a similar arrangement is found in the scorpion gill lamella, as seen in fig. 4, A, taken from Macleod. In *Ammocoetes* there are no well-defined branchial capillaries, but the blood circulates, as in the invertebrate gill, in a lamellar space; here also, as Nestler has shown, the opposing walls of the gill lamellæ are held in position by little pillar-like cells, as seen in fig. 4, B, taken from his paper.

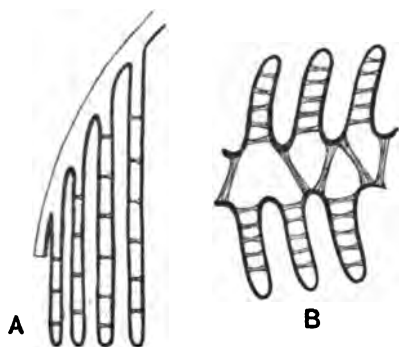


FIG. 4.—Comparison of branchial lamellæ of *Limulus* and *Scorpio* with branchial lamellæ of *Ammocoetes*. A, branchial lamellæ of *Scorpio* (after Macleod); B, branchial lamellæ of *Ammocoetes* (after Nestler).

In *Limulus* the blood flows into the lamellæ from sinuses or blood spaces (*b.s.*, fig. 3) at the base of each of the lamellæ, which sinuses are filled by a vessel which may be called the branchial artery, as it is the afferent branchial vessel. On each side of the middle line of the ventral surface of the body a larger longitudinal venous sinus exists, called by Milne Edwards the venous collecting sinus (L.V.S., fig. 5, and fig. 6, Part II.), which gives off to each of the branchial appendages on that side a well-defined afferent branchial vessel—the branchial artery. The blood of the branchial artery flows into the blood spaces between the anterior and posterior laminae of the appendage and thence into the gill lamellæ, from which it is collected into an efferent vessel or branchial vein, termed by Milne Edwards the branchio-cardiac canal, which carries it back to the dorsal heart. The position of the branchial artery and vein is shown in fig. 3, which

¹ *Archiv de Biol.*, vol. v., 1884, p. 1.

represents a section through the branchial appendage of *Limulus* at right angles to the cartilaginous branchial bar (*br. cart.*), just as fig. 2 represents a section through the branchial appendage of *Ammocoetes* at right angles to the cartilaginous branchial bar.

Further, the observations of Blanchard, Milne Edwards, Ray Lankester, and Benham concur in showing that in both *Limulus* and the scorpion group a striking and most useful connection exists between the heart and these two collecting venous sinuses,

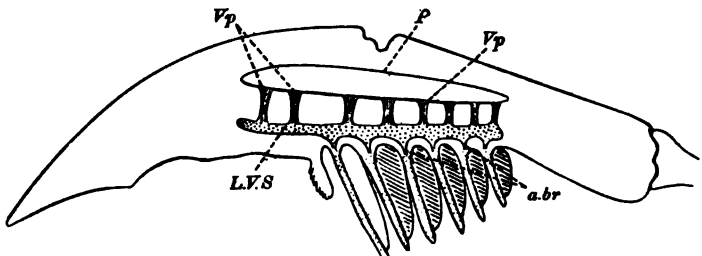


FIG. 5.—Longitudinal diagrammatic section through the mesosomatic region of *Limulus*, to show the origin of the branchial arteries (after Benham). *L.V.S.*, longitudinal venous sinus or collecting sinus; *a.br.*, branchial arteries; *V.p.*, veno-pericardiac muscles; *p.*, pericardium.

in the shape of a segmentally arranged series of muscular bands (*V.p.*, fig. 5, and fig. 6, Part II.), attached, on the one hand, to the pericardium, and on the other to the venous collecting sinus on each side. These muscular bands, to which Lankester and Benham have given the name of veno-pericardiac muscles, are so different in appearance from the rest of the muscular substance, that Milne Edwards did not recognise them as muscular, but called them "brides transparentes." Blanchard speaks of them in the scorpion as "ligaments contractiles," and considers that they act an important part in assisting the pulmonary circulation; for he says,¹ "en mettant à nu une portion du cœur, on remarque que ces battements se font sentir sur les ligaments contractiles, et déterminent sur les poches pulmonaires une pression qui fait aussitôt refluer et remonter le sang dans les vaisseaux pneumocardiaques." Lankester,² in discussing the veno-peri-

¹ *L'Organisation du Règne Animal. Arachnides*, by E. Blanchard, 1852, p. 94.

² "Notes of certain points in the Anatomy and Generic Characters of Scorpions," *Trans. of Zool. Soc.*, p. 374.

cardiac muscles of *Limulus* and the scorpions, says that these muscles probably contract simultaneously with the heart, and are of great importance in assisting the flow through the pulmonary system.

Precisely the same arrangement of veno-pericardiac muscles and of longitudinal venous collecting sinuses occurs in the scorpions. It is one of the fundamental characters of the group, and we may fairly assume that a similar arrangement existed in the extinct forms from which I imagine the vertebrate to have arisen.

Passing now to the condition of the branchial blood-vessels of *Ammocetes*, we see that the blood passes into the gill lamellæ from a blood space in the appendage, which can hardly be dignified by the name of a blood-vessel. This blood space is supplied by the branchial artery which arises segmentally from the ventral aorta, as seen in Miss Alcock's paper (fig. 4, Pl. II.). From the gill lamellæ the blood is collected into an efferent or branchial vein which runs, as seen in fig. 2, on the free edge of the diaphragm, and terminates in the dorsal aorta.

The ventral aorta is a single vessel near the heart, but at the commencement of the thyroid it divides into two, and so forms two ventral longitudinal vessels, from which the branchial arteries arise segmentally.

From this description it is clear that the vascular supply of the branchial segment of *Ammocetes* would resemble most closely the vascular supply of the *Limulus* appendage if the ventral aorta of the former was derived from two longitudinal veins homologous with the paired longitudinal venous sinuses of the latter.

A priori, such a derivation seems, on the face of it, highly improbable; and yet it is precisely the manner in which embryology teaches us that the heart and ventral aorta of the vertebrate have arisen.

One of the most striking peculiarities of the vertebrate consists in the fact that its heart arose as an organ for sending blood into the branchiæ, and not into the general body system. In invertebrates the systemic heart is the rule; in vertebrates only does the heart originate as a branchial heart.

Further, we see that in *Mammalia* and *Aves* the heart and

ventral aorta commence as a pair of longitudinal veins, one on each side of the commencing notochord.

If the embryo be removed from the yolk, the surface of the embryo covering these two venous trunks can be spoken of as the ventral surface of the embryo at that stage, and indeed we find that in the present day there is an increasing tendency to speak of this surface as the ventral surface of the embryo. Thus Mitsukuri, in his studies of Chelonian embryos, lays great stress on the importance of surface views; and when the embryo has been removed from the yolk, figures and speaks of its ventral surface; so also Locy and Neal find that the best method of seeing the early segments of the embryo is to remove the embryo from the yolk, and examine what they speak of as a ventral view. At the period, then, before the formation of the throat, we may say that on the ventral surface of the embryo at pair of longitudinal venous sinuses are found, one on each side of the mid-ventral line, which are in the same position with respect to the mid-axis of the embryo as the longitudinal venous sinuses in *Limulus*.

Then comes the formation of the throat by the extension of the layers of the embryo laterally to meet in the mid-line, and so form the pharynx, with the consequence that a new ventral surface is formed; these two veins, as is well known, travel round also, and, meeting together in the new mid-ventral line, form the subintestinal vein, the heart, and the ventral aorta.

What is true of Mammalia and Aves, P. Mayer¹ has shown to be true universally among vertebrates, so that in all cases the heart and ventral aorta have arisen by the coalescence in the new mid-ventral line of two longitudinal venous channels, which were originally situated one on each side of the notochord, in what was then the ventral surface of this part of the embryo. This history is especially instructive in showing how the pharyngeal region is formed by the growing round of the lateral mesoblast, *i.e.*, the muscular and other mesoblastic tissues of the branchial segments, and how the two longitudinal veins take part in this process. The phylogenetic interpretation of this embryological fact would be, that the new ventral surface of the vertebrate in this region is formed not only by the bran-

¹ *Mitth. a. d. Zool. Staz. z. Neapel*, vol. vii.

chial appendages, but also by the growth ventrally of that part of the original ventral surface which covered each longitudinal venous sinus.

I have never thought, said, or implied that the heart and ventral aorta were formed "by the tips of the legs where they grow together," as Minot¹ asserted at the Toronto meeting of the British Association. On the contrary, I have always looked upon the heart as formed from the two longitudinal venous collecting sinuses, which are situated, not on the tips of the appendages, but beneath the original ventral surface, and I consider that such formation embryologically points to the conclusion that the ventral surface of the *Ammocoetes* in the branchial region (meaning thereby the ventral surface of the animal after removal of the skin and somatic musculature) is formed partly from the original ventral surface of the arthropod *Limulus*-like ancestor, and partly from the appendages. The problem of its formation is of the same kind as that which meets us in considering how the ventral mesosomatic surface of the body of scorpions was formed.

When we bear in mind that almost all observers consider that the internal branchiæ of the scorpion group are directly derived from branchial appendages of a kind similar to those of *Limulus*, it is evident that such a branchial appendage as that of *Ammocoetes* might also have arisen from such an appendage, because in various respects it is easier to compare the branchial appendage of *Ammocoetes*, than that of the scorpion group, with that of *Limulus*.

In the case of the scorpions, various suggestions have been made as to the manner in which such a conversion may have taken place.

The most likely explanation is that given by Macleod,² in which each of the branchiæ of the scorpion group are directly compared with the branchial part of the *Limulus* appendage which has sunk into and amalgamated with the ventral surface.

Lankester has put forward two most improbable guesses, the first of which,³ viz., that the hollow insertions of the tendons of

¹ *American Naturalist*, vol. xxxi., 1897.

² *Archiv. de Biolog.*, tom. v., 1884, p. 1.

³ "*Limulus* an Arachnid," *Quart. Jour. Micr. Sci.*, 1881, vol. xxi. p. 504.

the branchio-thoracic muscle in each branchial segment of *Limulus* became the stigmata of the scorpion, he himself has given up; the second,¹ however, although of equal value, he has not yet retracted, but, on the contrary, he looks on it as better than Macleod's suggestion. He considers that the branchial appendage of the *Limulus*-like form was invaginated into the venous sac even to the very ends of its lamellæ; turned inside out, as he explains, just as a glove fastened to the margin of a box at the wrist might be turned outside in up to its finger-tips, and so lie entirely within the box without altering its fastenings at the wrist.

The great improbability of this suggestion is seen in the fact, as already stated, that the internal surfaces of the lamellæ, both in scorpion and in *Limulus*, are joined together by a series of little pillars (colonnets), in precisely the same manner in the two cases. Such an invagination as Lankester supposes necessitates the disappearance or breaking down of these connecting bands in the case of *Limulus*, and their re-formation in the fine divisions of the blood space between the introverted lamellæ in the case of the scorpion. That such an occurrence should occur, and, as the end result, produce branchial lamellæ so remarkably similar in all respects as are those of *Limulus* and scorpion, is, to say the least of it, highly improbable; and seeing that Lankester has made no attempt to controvert Macleod's argument, and also that Brauer's² work on the embryological development of the scorpion lung-book is compatible with Macleod's suggestion, it seems advisable to accept his hypothesis as the most reasonable one at the present day.

According to this view, the modification which has taken place in transforming the branchial *Limulus* appendage into the branchial scorpion appendage is a further stage of the process by which the *Limulus* branchial appendage itself has been formed, viz., the getting rid of the free locomotor segments of the original appendage thus confining the appendage more and more to the basal branchial portion. So far has this process been carried in the scorpion that all the free part of the appendage has disappeared; apparently, also, the intrinsic muscles of the append-

¹ *Trans. Zool. Soc.*, 1885, vol. xi. p. 367.

² *Zeitsch. f. Wissensch. Zool.*, 1895, vol. lix. p. 351.

age have gone, with the possible exception of the post-stigmatic muscle; so that any direct comparison between the branchial appendages of *Limulus* and the scorpions is limited to the comparison of their branchiæ, their nerves, and their afferent and efferent blood-vessels.

In the case of *Ammocoetes* the comparison must have been with water-breathing scorpions, such as existed in past ages in the forms of *Eurypterus*, *Pterygotus*, *Slimonium*, rather than with air-breathers, and with the crowd of trilobite and *Limulus*-like forms which were in past ages so predominant in the sea; forms, in some of which the branchial appendages had already become internal, but which, from the very fact of being water-breathers, probably resembled, in respect to their respiratory apparatus, *Limulus* rather than the present-day scorpion.

On the assumption that the branchial appendages of *Ammocoetes*, like the branchial appendages of the scorpion group, are comparable with those of *Limulus* to a certain extent, it becomes a matter of great interest to inquire whether the mode in which respiration is effected in *Ammocoetes* resembles most that of *Limulus* or of scorpion.

The Origin of the Branchial Musculature.

The difference between the movements of respiration in *Limulus* and those of the scorpions consists in the fact that although in both cases respiration is effected mainly by dorso-ventral muscles, these muscles are not homologous in the two cases: in the former, the dorso-ventral appendage muscles are mainly concerned; in the latter, the dorso-ventral somatic muscles.

The paper of Benham¹ gives a full description of the musculature of *Limulus*, and according to his arrangement the muscles are divided into two sets, longitudinal and dorso-ventral. Of these latter, each mesosomatic segment possesses a pair of dorso-ventral muscles, attached to the mid-ventral mesosomatic entochondrite and to the tergal surface (fig. 6, Part II.).

These muscles are called by Benham the vertical mesosomatic muscles. I shall call them the somatic dorso-ventral muscles, in

¹ *Trans. Zool. Soc.*, vol. xi. p. 314.

contradistinction to the dorso-ventral muscles of the branchial appendages. Of these latter, the two chief are the external branchial (fig. 3, m_3) and the posterior entapophysio-branchial (fig. 3, m_1); a third muscle is the anterior entapophysio-branchial (fig. 3, m_2). Of these muscles, the posterior entapophysio-branchial is closely attached along the branchial cartilaginous bar up to its round-headed termination on the anterior surface of the appendages. It is this attachment, apparently, which has led Benham to describe it as attached to the posterior lamella, and therefore to call it the posterior entapophysio-branchial.¹ The anterior entapophysio-branchial muscle is attached to the branchial cartilage near the entapophysis.

In the case of the scorpion, as described by Miss Beck,² the branchial appendage has become reduced to the branchiæ, and the intrinsic appendage muscles have entirely disappeared, with the possible exception of the small post-stigmatic muscle; while the dorso-ventral somatic muscles, which are clearly homologous with the corresponding muscles of *Limulus*, have remained, and become the essential respiratory muscles.

Of these two types of respiratory movement it is quite conceivable that in the water-breathing scorpions of old time and their allies, the dorso-ventral muscles of their branchial appendages may have continued their role of respiratory muscles, and so have given origin to the respiratory muscles of the ancestors of *Ammocœtes*. The respiratory muscles of *Ammocœtes* are three in number, and have been described by Nestler and Miss Alcock as the adductor muscle, the striated constrictor muscle, and the tubular constrictor muscle (fig. 2, *m.add.*, *m.c.s.*, and *m.c.t.*

Of these, the constrictor muscle is in close contact with the cartilaginous bar, while the adductor is attached to the cartilage only at its origin and insertion, and the tubular muscles have nothing whatever to do with the cartilage at all, being attached ventrally to the connective tissue in the neighbourhood of the ventral aorta, and dorsally in the mid-line between the dorsal aorta and the notochord.

¹ I find, on looking again at his drawings, that the sclerite (*p.*, in his fig. 3, pl. 74) which I stated in Part II. of this series, vol. xxxii. p. 564, apparently covered the cartilaginous bar, is not in that position, but is a marked sclerite, to which, as described by him, the fibres of the external branchial are attached.

² *Trans. Zool. Soc.*, vol. xi.

The close relationship of the constrictor muscle to the cartilaginous branchial bar does not favour the surmise that this muscle is homologous with the dorso-ventral somatic muscle of the scorpion, but is directly in accordance with the view that such muscle is homologous with one of the dorso-ventral appendage muscles, such as the posterior entapophysio-branchial muscle of the *Limulus* appendage, especially in view of the homology of the *Ammocoetes* branchial cartilage with the *Limulus* branchial cartilage. I am therefore inclined to look upon the constrictor and adductor muscles of the *Ammocoetes* branchial segment as more likely to have been derived from dorso-ventral muscles which belonged originally to a branchial appendage such as we see in *Limulus*, than from dorso-ventral somatic muscles, such as the vertical mesosomatic muscles, which are found both in *Limulus* and scorpion. In other words, I am inclined to hold the view that the somatic dorso-ventral muscles have disappeared in this region in *Ammocoetes*, while dorso-ventral appendage muscles have been retained, i.e., the exact reverse to what has taken place in the air-breathing scorpion.

I am especially inclined to this view because of the manner in which it fits in and explains v. Wijhe's results. Ever since Schneider divided the striated muscles of vertebrates into parietal and visceral, such a division has received general acceptance, and as far as the head region is concerned, has received an explanation in v. Wijhe's work; for Schneider's grouping corresponds exactly to the two segmentations of the head mesoblast discovered by v. Wijhe, i.e., to the somatic and splanchnic striated muscles according to my nomenclature. Of these two groups the splanchnic or visceral striated musculature, innervated by the Vth, VIIth, IXth, and Xth nerves, is derived from the musculature of the corresponding appendages, and is, speaking generally, dorso-ventral in direction in *Ammocoetes*; the somatic musculature, on the other hand, is clearly divisible, in the head region, into two sets, a spinal and a cranial set. The somatic muscles innervated by the spinal set of nerves, including in this term the spino-occipital or so-called hypoglossal nerves, are in *Ammocoetes* most sharply defined from all the other muscles of the body. They form the great dorsal and

ventral longitudinal body muscles, which extend dorsally as far forward as the nose, are developed embryologically quite distinctly from the others, being formed as muscle plates (Kästchen). On the other hand, the cranial somatic muscles are the eye-muscles, the formation of which resembles the visceral muscles, and not the spinal somatic; their direction is not longitudinal, but dorso-ventral; they cannot, in my opinion, be referred to the somatic trunk muscles, and must therefore form a separate group to themselves, so that the striated musculature of the *Ammocoetes* must be divided into—(1) the visceral muscles; (2) the longitudinal somatic muscles; and (3) the dorso-ventral somatic muscles. Of these, the 1st, on the view just stated, represent the original appendage muscles; the 2nd belong to the spinal region, and will be considered with that region; the 3rd represent the original segmental dorso-ventral somatic muscles, which are so conspicuous in the musculature of the *Limulus* and the scorpion group.

The discussion of this last statement will be given when I come to deal with the prosomatic segments of *Ammocoetes*. I wish here simply to point out that v. Wijhe has shown that the eye-muscles develop from his 1st, 2nd, and 3rd dorsal mesoblastic segments, and therefore represent the somatic muscles belonging to those segments, while no development of any corresponding muscles takes place in the 4th, 5th, and 6th segments; so that if the eye-muscles represent a group of dorso-ventral somatic muscles, such muscles have been lost in the 4th, 5th, and 6th segments. These latter segments are, however, the glosso-pharyngeal and vagus segments, the branchial musculature of which is derived from the ventral segments of the mesoderm. In other words, v. Wijhe's observations mean that the dorso-ventral somatic musculature has been lost in the branchial and mesosomatic region, while the dorso-ventral appendage musculature has been retained, and that, therefore, the mode of respiration in *Ammocoetes* more closely resembles that of *Limulus* than of *Scorpio*.

These striated voluntary muscles, formed either after the type of the somatic or of the visceral muscles, form the whole of such musculature in the higher vertebrates, and it is significant, on the view advanced in these papers, to find that Biedermann

states, in his *Electro-Physiology*, under the heading "Cross-striated multinuclear muscle fibres,"—"Among invertebrates these occur in Arthropoda only; in vertebrates collectively they form the chief bulk of muscle."

In *Ammocoetes*, however, the striated voluntary muscles consist not only of the somatic and visceral striated, but also of a well-marked kind of muscle fibre, which has been called the tubular striated muscle fibre. The nature of this muscle is

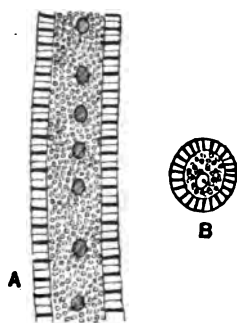


FIG. 6.—A tubular muscle fibre of *Ammocoetes*. A, Portion of fibre seen longitudinally; B, transverse section of fibre (osmic preparation); black dots on fat globules.

shown in fig. 6, and we see that it markedly resembles certain invertebrate muscles and also embryonic vertebrate muscle. Such muscle is found in the vertebrate kingdom only in *Ammocoetes*. It is found only in connection with the movements of respiration, forming the series of tubular constrictor muscles of the branchial segments and the greater part of the musculature of the velum; these latter muscles take part in the respiratory act, contracting synchronously with the branchial muscles. It is represented in the branchial region by simple hatching in figs. 1 and 2, Pl. III.), and, as shown by Nestler and Miss Alcock (fig. 4, Pl. II. of her paper, *m. con. tub.*), it does not in the branchial region arise from, and is not connected with, any cartilaginous structure, but is attached at its dorsal end to the tissue near the notochord, and at its ventral end to the connective tissue in the neighbourhood of the ventral aorta.

Most extraordinary of all, according to Miss Alcock's observations, although segmentally arranged, these tubular constrictor

muscles are not innervated by the vagus and glosso-pharyngeal nerves, but by a separate nerve, which arises from the central nervous system at the level of the facial, and is devoted entirely to the supply of these special segmental muscles.

I have looked through much of the musculature of *Limulus* in order to find out differences of histological structure, and have as yet found that the heart muscle and the veno-pericardiac muscles alone show a more embryonic structure, and therefore resemble somewhat the tubular muscles of *Ammocoetes*. At present, although I feel that it is premature to attempt any comparison between the veno-pericardiac muscles of *Limulus* and these tubular muscles of *Ammocoetes*, yet it is worth pointing out that it is perfectly possible, and indeed probable, that the shifting of the two ventral longitudinal sinuses to form the subintestinal vein, heart, and ventral aorta, in the manner already explained, would carry with it the veno-pericardiac muscles, attached as they are to the venous longitudinal sinuses, and so bring these muscles into the position of the paired tubular constrictor muscles of *Ammocoetes*, especially when we find that these latter muscles are attached to the tissue near the ventral aorta, and not to the cartilage, as are the constrictor muscles proper. A further significant fact in accordance with this view is, that they are of the nature of rudimentary muscles, seeing that they disappear at transformation. Such a suggestion would be immensely strengthened if it were found that the nerve supply of the veno-pericardiac muscles in *Limulus* was different to that of the neighbouring musculature. At present, I do not know how these muscles are supplied; but seeing that they contract synchronously with the heart, according to Milne Edwards, their innervation must be more closely connected with that of the heart than of the neighbouring dorso-ventral muscles.

From the evidence given, I conclude that it is perfectly possible to look upon the respiratory or branchial part of the pharyngeal chamber of *Ammocoetes* as formed by a series of branchial segments, which were originally the mesosomatic or branchial appendages of the arthropod ancestor. Of these segments (as seen in figs. 1 and 2, Pl. III.), six are alike, five of them belonging to the vagus nerve and one to the glosso-

pharyngeal; the uppermost or hyoid segment, belonging to the facial, and the lowermost vagus segment are different, and require separate consideration.

In addition to these branchial segments, this region is covered over by the somatic musculature and the skin. If we may judge from the nerve supply, this somatic covering did not originally belong to this region, but to the segments posterior to it, since all the somatic musculature is innervated by spinal and not by cranial nerves. Another possibility would be, that in the concentration and cephalisation which took place to form the medulla oblongata, the appendage nerves only took part, while the somatic part of the mesosomatic ganglia remained behind and formed the spino-occipital and upper cervical region, so accounting for the ascending root of the trigeminal nerve.

Between this somatic covering and the branchial segments, Fürbringer,¹ following Boveri, believes that a chamber, the atrial chamber (peribranchial Raum), originally existed. He says, "I am inclined, therefore, to believe that the ancestors of the vertebrates originally possessed gill clefts, which opened freely to the exterior, and afterwards were protected by the growth ventrally of a lateral fold of the body-wall, in consequence of which an atrial chamber was formed, into which the gill slits opened. This chamber, so formed, as well as the branchial apparatus itself, attained to a special high development in *Amphioxus* (*Akraniern*), while in the vertebrates (*Kranioten*), by means of a steady growing together of the body-fold with the gills, the cavity gradually diminished. In consequence of this junction of the body-wall with the branchial basket, the atrial chamber became closed, and therefore new external gill-slit openings were of necessity formed, to enable the gills to continue their function; this took place either as in the *Myxinoids*, or as in *Petromyzon* and the higher fishes, by the external openings breaking through this somatic covering."

The Origin of the Branchial Sense Organs.

This view of Fürbringer's, that an amalgamation has taken place between this somatic covering and the branchial append-

¹ "Über die Spino-occipitalen Nerven," etc., *Festschrift f. C. Gegenbaur*, Leipzig, 1897, p. 655.

ages, is borne out by Miss Alcock's discovery of the manner in which the special sense organs known as epithelial pits are innervated in this branchial region. As is seen in fig. 1, A and B, of her paper, each branchial nerve sends a dorsal and ventral branch to the surface of the skin for the exclusive supply of these special sense organs, so that the somatic surface of the *Ammocœtes* is, as is seen, divided into perfectly regular segments by these nerves and their sense organs.

From the evidence which she has given, and that afforded by Strong¹ and others, it appears that the system of so-called lateral line organs over the whole of the body is innervated from that region of the medulla oblongata which gives origin to the facial, vagus, and glosso-pharyngeal nerves. It has no connection with the trigeminal or with any of the spinal nerves; to use the terms of this paper, it has arisen in connection with mesosomatic branchial segments, and not with prosomatic or metasomatic segments. In these remarks I confine myself to the known organs of the lateral line, and refrain at this juncture from expressing any opinion whether the auditory apparatus ought to be included in this system: the consideration of the auditory nerve and organ may well form a separate part of this series of papers.

As to the function of this system of sense organs, it appears to be more and more certain, in the present day, that they are for the purpose of estimating the depth of the water, that they are pressure organs, and so concerned in the equilibration of the animal.

In the *Ammocœtes* these organs appear to be represented by the simple epithelial pits, as described by Miss Alcock; and we see that in this case, as in the higher fishes, although the organs themselves are situated on the external skin, their nerves never arise from the neighbouring somatic skin nerves, but always from the underlying branchial nerves. The conclusion, therefore, in accordance with the rest of this paper is, that such segmented sense organs, which were for the purpose of estimating depth of water, must have existed on the mesosomatic branchial appendages of the vertebrate ancestor, and have still remained, owing to the importance of their function, when such

¹ See Miss Alcock's paper with reference to this statement.

appendages have been reduced to the branchial-bearing diaphragms, as already explained. That such an explanation is not improbable is given by the fact that on the branchial mesosomatic appendages of *Limulus*, and on these appendages *viz.* a series of peculiar sense organs are found, which, from their structure, seem more likely to be pressure organs than anything else.

We see that in *Limulus* the basal part of the appendage which carries the branchiæ constitutes by far the greatest part of the appendage, and that the remaining segments have dwindled down to mere remnants, and have practically lost all locomotor power.

They still, however, retain in a marked manner certain special sense organs, which are very conspicuous on the limb segments as bluish, circular, blister-like swellings. They are figured in fig. 6 (vol. xxxii. p. 563) of Part II. of this series of papers, and have been described by Gegenbaur¹ in his description of a *Limulus*, as far as the cuticular appearances are concerned. The surface of these swellings is much softer than the surrounding chitin, and is covered over with beautiful chitinous goblet-like formations, each of which is capable of protruding beyond the level of the surrounding surface, or sinking into a depression on that surface exactly shaped to receive it; each goblet is like a wide-mouthed, shallow champagne glass, with the open mouth on the surface and the stem sunk into the chitinous layers. At the bottom of the goblet is an orifice which leads to a tube passing spirally through the chitinous layer to the special sense organ beneath. The shape of these goblets, which are of different sizes, and the ease with which they can move in their socket, the great probability that each one is connected with a special nerve fibre, all seem to me to point to their being of the nature of special pressure organs, rather than any other kind of sense organ. I hope, however, to be able, in a separate communication, to give a fuller description of their structure.

If they are organs for estimating the depth of the water, it is easy to understand that although branchial sense organs of this nature might be very essential to the inhabitants of the sea, yet

¹ *Abhand. d. Naturforsch. Gesell. z. Halle*, vol. iv., 1858, p. 231, figs. 4 and 5.

they would not be retained in forms like the scorpion and Thelyphonus, etc., which live on the land, just as the pressure system of the lateral line canals is confined to the vertebrate water-dwellers, and disappears as soon as the animal takes to dry land. On the other hand, if the animal still remained in the sea, but, like the extinct sea scorpions or the theoretical ancestors of the Ammocetes, lost more and more all the distal portions of its branchial appendages, it is more probable than not that it would still retain these special pressure organs, together with their nerves, seeing how great must be their importance in animals living at varying depths.

If, then, by some such amalgamation of ventral surface, branchial appendage, and somatic shell as I have suggested, the basal parts of the branchial appendages became converted into the branchiæ of forms like Ammocetes, it might well happen that the only remnant of the distal parts of the appendage which has survived is to be found in the segmentally arranged epithelial pits of this region, together with the branchial nerves which innervate them.

Whether there is any structural relationship between these branchial sense organs of Limulus and the epithelial pits of Ammocetes I am not at present prepared to say. I only wish to point out here the striking fact that in Ammocetes the innervation of the whole system of lateral line organs known as 'epithelial pits' is confined to the branchial nerves, and that in Limulus these very special sense organs are confined absolutely to the distal parts of the branchial appendages.

I have now given my reasons why I consider that the glosso-pharyngeal and vagus nerves were originally the nerves to a series of mesosomatic branchial appendages, each of which is still traceable in the respiratory chamber of Ammocetes, and gives the type form from which to search for other serially homologous, although it may be specially modified, segments.

The Origin of the Hyoid Segment ; the Meaning of the VIIIth Nerve.

As is seen from figs. 1 and 2, Pl. III., the segment immediately in front of the glosso-pharyngeal, i.e., the hyoid segment supplied by the facial nerve, is clearly of the same order as the rest of

the branchial segments, and yet is markedly unlike in various respects. It possesses branchiæ only on its posterior aspect; it does not possess a cartilaginous bar, but in its place a mucocartilaginous bar, which becomes cartilaginous at transformation; it possesses only a few of the tubular constrictor muscle fibres, as noticed in Miss Alcock's paper. In addition to the branchial portion of this segment, the figures show that the anterior portion of the segment is largely taken up by blood spaces, but in addition carries the ciliated groove (*Ps. br.*), called by Dohrn pseudo-branchiale Rinne, which leads directly into the thyroid gland, and connects this segment with the thyroid.

As Miss Alcock has shown, the facial nerve is not only the branchial nerve of the first or hyoid branchial segment, but also is the nerve of this thyroid segment; so that we may define this facial or hyoid segment, which, according to the previous argument, was derived from the first mesosomatic appendage, as composed of two parts, viz., a posterior branchial part, strictly homologous with the branchial appendages of the glosso-pharyngeal and vagus nerves, and an anterior part, which carries the thyroid gland and ciliated groove.

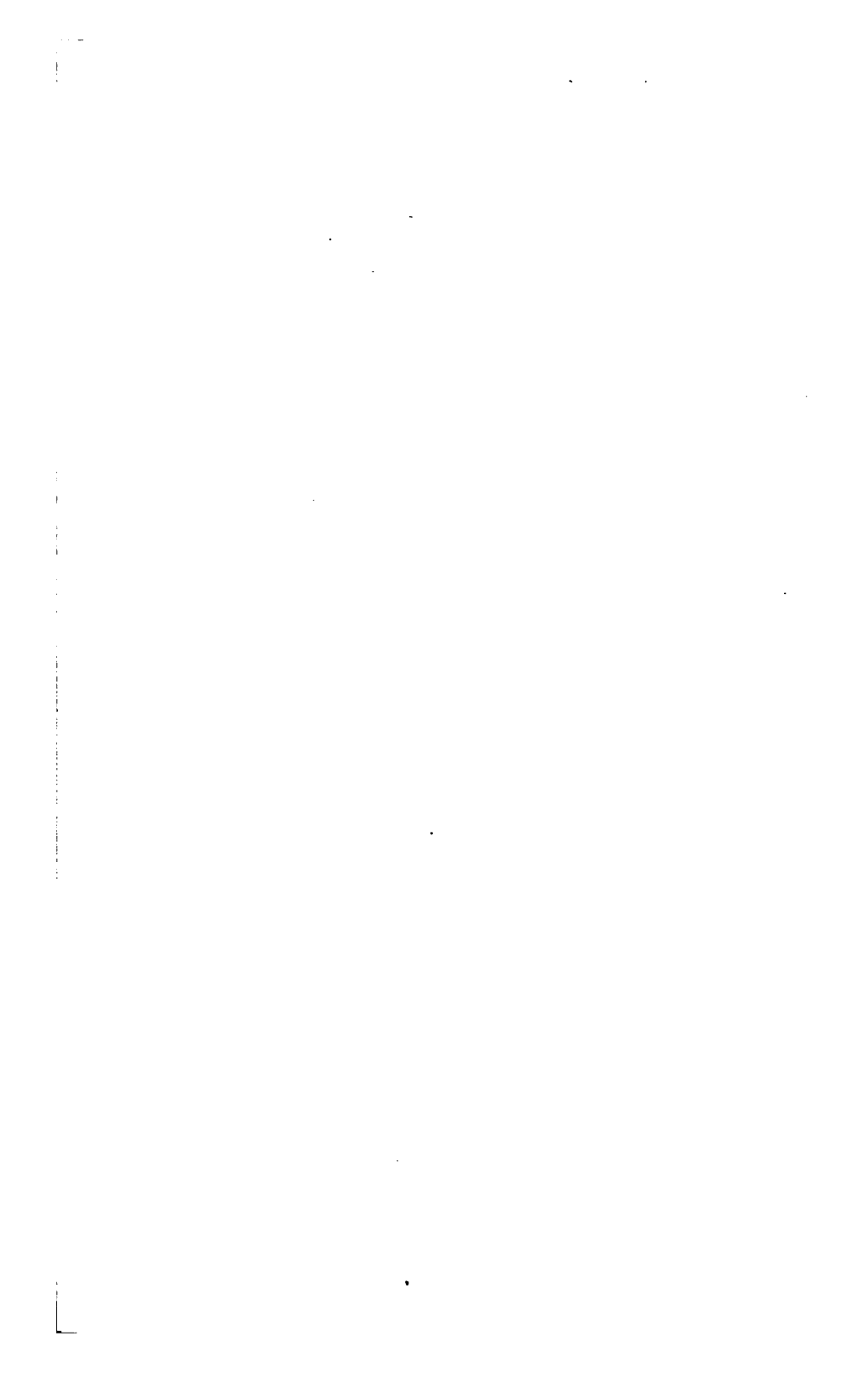
It was, I must confess, with a feeling of considerable pleasure that I recalled the condition of affairs in the old sea scorpions *Eurypterus*, *Pterygotus*, etc., and in the still existing *Thelyphonus*, *Phrynus*, etc. In these forms, the first mesosomatic appendage is the operculum, and in all cases is double, the posterior part possessing branchiæ, while the anterior and median part carries the terminal portions of the genital organs. In accordance, then, with the whole of the rest of the argument, this would imply that the thyroid gland of *Ammocetes* was the remnant of some portion of the terminal genital apparatus of the arthropod ancestor; and, conversely, if such a resemblance was shown to exist, my argument would be distinctly strengthened. I examined, therefore, the nature of the terminal genital apparatus in the scorpion, and, as stated in my address at Liverpool, found an organ very similar in structure to the very peculiar thyroid of *Ammocetes*. The discussion of the meaning of the thyroid gland and the position of the facial nerve will form a separate part of these series of papers. I have only briefly stated my conclusions here in order to finish in this part the discussion of the meaning of the branchial segmentation.

As far, then, as the branchial or opisthotic segmentation is concerned, the evidence deduced from the study of *Ammocætes* is in full harmony with the evidence already given by the study of the brain and cartilaginous framework, and leads to the conclusion that the facial, glosso-pharyngeal, and vagus nerves were nerves which originally supplied branchial appendages which, by amalgamation with each other and the ventral surface of the arthropod ancestor, formed a respiratory chamber. The way in which, in all probability, such a chamber took on the function of an alimentary canal, will be considered at the end of the part dealing with the segmentation of the head, and therefore after finishing the discussion on the pro-otic segments.

EXPLANATION OF PLATE III.

Fig. 1. Ventral half of head region of *Ammocætes*.

Fig. 2. Dorsal half of head region of *Ammocætes*. Branchial and visceral muscles coloured light red. Somatic muscles a deeper red. Tubular constrictor muscles distinguished from striated constrictor muscles by simple hatching. *Tent. m.c.*, muco-cartilage of the tentacles; *Ps. br.*, pseudo-branchial groove; *Vel. m.c.*, muco-cartilage of the velum; *Th. op.*, orifice of thyroid; *Hy. m.c.*, muco-cartilage of the hyoid segment; *Inf.*, position of old œsophagus; *Br. cart.*, branchial cartilages; *Ser.*, median serrated flange of velum; *Sp.*, space between somatic and splanchnic muscles; *Tr.*, trabeculæ; *P.*, pigment in centre of each branchial appendage; *H.*, heart.



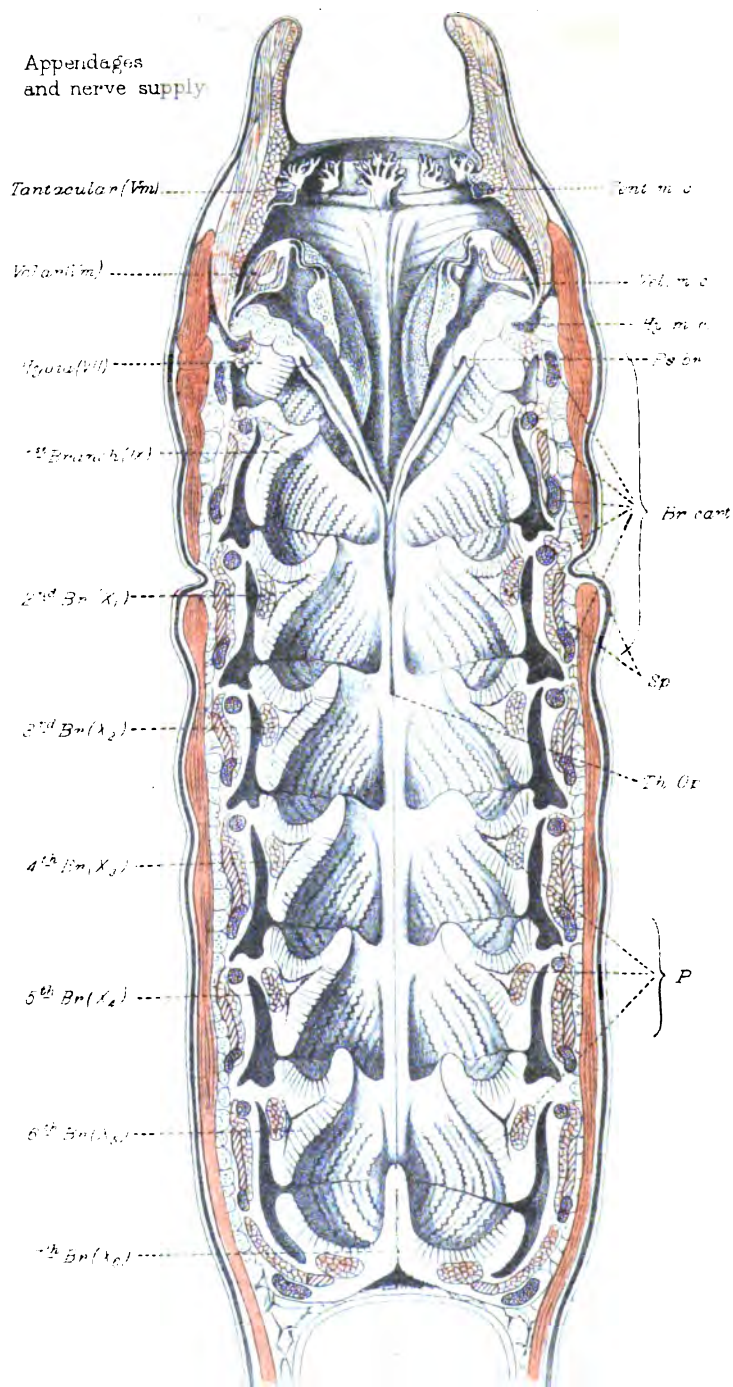


Fig 1

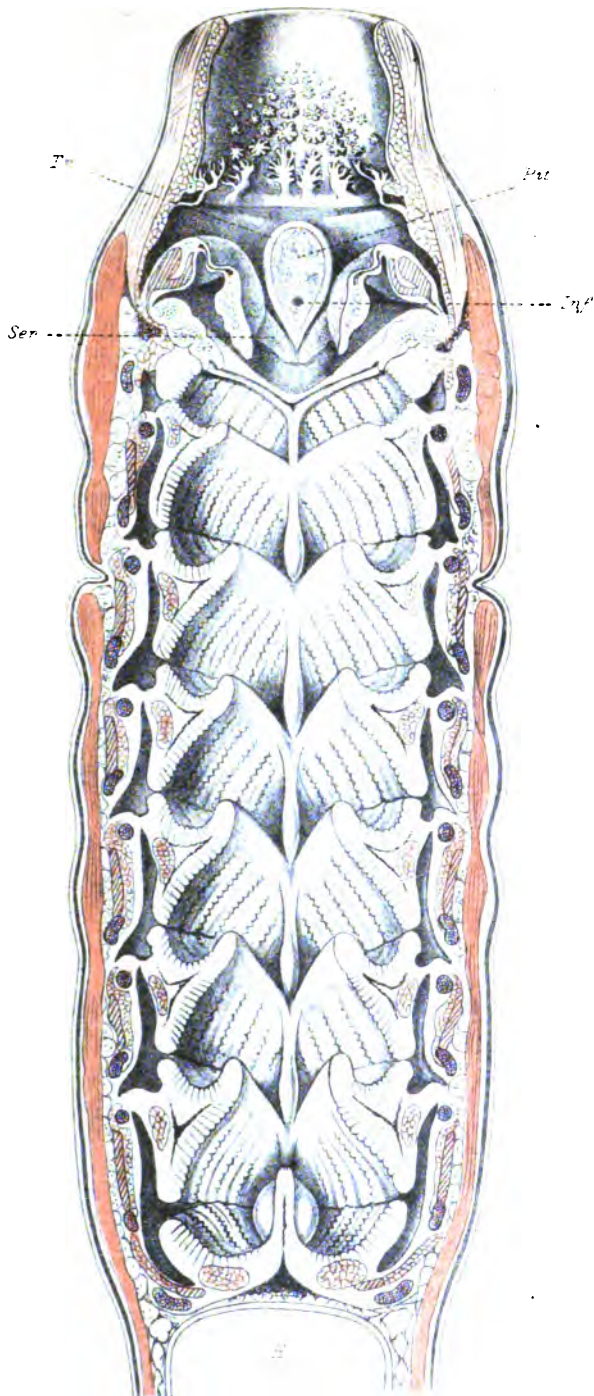
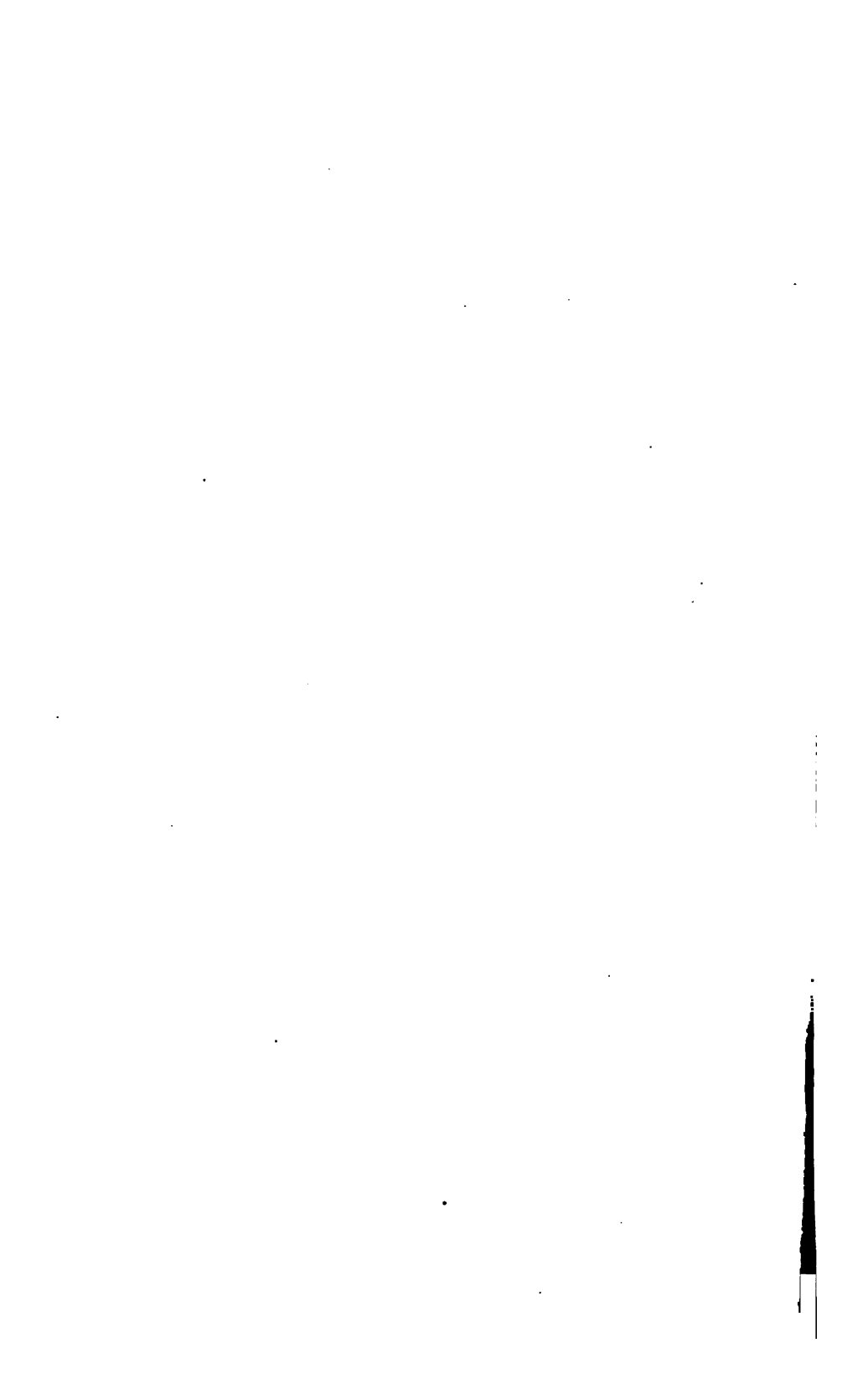


Fig. 2.



EIGHTH REPORT OF THE COMMITTEE OF COLLECTIVE INVESTIGATION OF THE ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND, FOR THE YEAR 1897-98.¹ Reported by F. G. PARSONS and ARTHUR ROBINSON.

THE following questions were issued by the Committee of Collective Investigation of the Anatomical Society in September 1897 :—

1. The Extensor Muscles of the Thumb.

- (a) Their degree of division.
- (b) Their exact mode of insertion.
- (c) The frequency of absence of the extensor brevis (primi internodii) pollicis.

2. The Popliteal Artery.

- (a) Its place of division.
- (b) The course of the anterior tibial artery in cases of high division.
- (c) The presence and point of origin of the posterior tibial recurrent and superior fibular branches.
- (d) The place of origin of the peroneal artery.

3. The Azygos Veins.

- (a) Their mode of origin in the abdomen or thorax.
- (b) Their communications—
 - (a) Between the azygos veins of the two sides.
 - (β) Between the azygos veins and the inferior vena cava, renal, and lumbar veins.

QUESTION I.

1. The Extensor Muscles of the Thumb.

- (a) Their degree of division.
- (b) Their exact mode of insertion.
- (c) The frequency of absence of the extensor brevis (primi internodii) pollicis.

¹ The Seventh Report will be found on page 164 of the *Journal of Anatomy*, vol. xxxii.

Reports have been received from the following gentlemen:—

Dr Low, Aberdeen University; Mr Walker Hall, Owens College, Manchester; Mr C. H. Bullen, Mason University College, Birmingham; Dr Walter Graham, University College, Liverpool; Dr H. Batty Shaw, University College, London; Mr C. Nitch, St Thomas's Hospital; Mr N. Navarra, Middlesex Hospital.

(a) *The degree of division of the muscles.*—Reports of 131 observations have been sent in. Of these the three muscular bellies were distinct in 81 (61·8 p.c.).

In 48 cases (36·6 p.c.) the muscular bellies of the extensor ossis metacarpi pollicis and extensor brevis pollicis were more or less fused. The fusion in these cases varied from one inch from the origin to complete union. In one case the muscular bellies of the extensor longus and extensor brevis pollicis were fused.

In one case all three muscular bellies were fused.

In one case the muscular belly of the extensor longus pollicis was fused with that of the extensor indicis. Unfortunately, many of the recorders have omitted to state the side on which the observations were made, but from the records which we have on this point we are of opinion that the side of the body has little or nothing to do with the fusion of the muscular bellies.

(b) *The exact mode of insertion of the muscles.*—Of the insertion of the extensor ossis metacarpi pollicis there are 127 records. Of these, 60 are on the right side, 51 on the left, and in 16 the side is not stated.

We find that there are 13 different ways in which the extensor ossis metacarpi pollicis may be inserted, and these we propose to arrange according to the frequency with which they occur.

1. Into the metacarpal bone of the thumb, the trapezium, and the abductor pollicis, 32 (25·2 p.c.). Of these, 18 are on the right side and 14 on the left.

2. Into the metacarpal bone and abductor pollicis, 26 (20·5 p.c.). Of these, 14 are on the right side, 11 on the left, and in 1 the side is not stated.

3. Into the metacarpal bone and trapezium, 24 (18·9 p.c.). Of these, 5 are on the right side, 6 on the left, and in 13 the side is not stated.

4. Into the metacarpal bone only, 13 (10·2 p.c.). Of these, 8 are on the right side, 3 on the left, and in 2 the side is not stated.

5. Into the metacarpal bone, trapezium, and opponens, 7 (5·5 p.c.). Of these, 4 were on the right side and 3 on the left.

6. Into the metacarpal bone, trapezium, abductor, and opponens pollicis, 7 (5·5 p.c.). Of these, 4 were on the right side and 3 on the left.

7. Into the metacarpal bone, abductor, and opponens pollicis, 5 (3·9 p.c.). Of these, 3 were on the right side and 2 on the left.

8. Into the metacarpal bone and carpo-metacarpal ligament, 3 (2·3 p.c.). Of these, 1 was on the right side and 2 were on the left.

9. Into the metacarpal bone, proximal phalanx, and abductor

pollicis, 3 (2·3 p.c.). Of these, 1 was on the right side and 2 were on the left.

10. Into the metacarpal bone and proximal phalanx, 2 (1·6 p.c.). Both of these were on the left side.

11. Into the metacarpal bone, trapezium, and proximal phalanx, 2 (1·6 p.c.). Of these, one was on the right side and the other on the left.

12. Into the metacarpal bone, trapezium, abductor pollicis, and proximal phalanx, 2 (1·6 p.c.). Of these, one was on the right side and the other on the left.

13. Into the metacarpal bone and opponens pollicis, 1 (·8 p.c.). This case was on the left side.

It will be noticed from the foregoing that in every case the extensor ossis metacarpi pollicis was inserted into the metacarpal bone.

Of the insertion of the extensor brevis (primi internodii) pollicis there are 118 records. Of these, 63 are on the right side, 51 on the left, while in 4 the side was not stated.

There are three ways in which the muscle may be inserted. These are arranged in their order of frequency.

1. Entirely into the proximal phalanx of the thumb, 85 (72 p.c.). Of these, 49 were on the right side, 34 on the left, and in 2 the side was not stated.

In several of these cases it was noticed that the extensor brevis was partly inserted into the metacarpo-phalangeal capsule; but as, apparently, only a certain number of contributors had directed their attention to this point, we have refrained from attempting any statistics.

2. Partly into the proximal phalanx and partly with the extensor longus pollicis into the terminal phalanx, 25 (21·2 p.c.). Of these, 12 were on the right side, 11 on the left, and in 2 the side was not stated.

3. Entirely into the terminal phalanx with the extensor longus pollicis, 8 (6·8 p.c.). Of these, 2 were on the right side and 6 on the left.

From the report of Mr Nitch, of St Thomas's Hospital, it appears that the extensor brevis pollicis, at its insertion, spreads out in a fan-shaped manner, and that the lateral fibres of the fan may, if they are well developed, curve backward, and be continuous with some of the fibres of insertion of the abductor pollicis on the one side, and of the adductor obliquus pollicis on the other.

Of the insertion of the extensor longus pollicis, there are 129 records. Of these, 64 are on the right side, 57 on the left, while in 8 the side is not stated. In every case the tendon is inserted into the terminal phalanx, sometimes alone, sometimes after having received a slip from the extensor brevis, sometimes after having given a slip to the proximal phalanx, either in conjunction with, or independently of, the extensor brevis.

1. Entirely into the terminal phalanx without any connection with the extensor brevis, 109 cases (84.5 p.c.). Of these, 57 were on the right side, 48 on the left, while in 4 the side was not stated.

2. Into the terminal phalanx, after having received a slip from the extensor brevis, 16 cases (12.4 p.c.). Of these, 6 were on the right side, 6 on the left, while in 4 the side was not stated.

3. Into the terminal, after having given off a slip to the proximal phalanx, 4 cases (3.1 p.c.). Of these, 1 was on the right side and 3 were on the left.

In these 129 cases, the tendon was divided into 2 in 7 (5.4 p.c.),¹ while in 3 cases it was divided into 3 (2.3 p.c.).

Only two observers paid any attention to the relation of the tendon of the extensor longus pollicis to the short muscles of the thumb, but from these it appears that, in the greater number of cases, the tendon is joined by an expansion from the abductor pollicis on the radial side, and from the adductor obliquus pollicis on the ulnar. In one case the tendon of the extensor longus pollicis was joined by a slip from the extensor indicis before its insertion.

In 2 cases out of 131 (1.5 p.c.) the extensor longus pollicis was stated to be absent, and in both of these (one on the right side and the other on the left) the extensor brevis was also absent, so that no long extensor tendons passed to the thumb. The condition of the short muscles of the thumb in these cases was unfortunately not noticed.

(c) *The frequency of absence of the extensor brevis (primi internodii) pollicis.*—Out of 126 observations, the extensor brevis was absent in 8 (6.35 p.c.). Of these, 1 was on the right side and 7 were on the left.

SUMMARY OF QUESTION I.

1. In more than half the cases the extensors of the thumb are distinct at their origins, but when there is any fusion it is usually between the extensor ossis metacarpi and the extensor brevis pollicis.

2. The extensor ossis metacarpi pollicis is always inserted into the metacarpal bone of the thumb, but in a very large number of cases it is also inserted into the trapezium and abductor pollicis.

3. The extensor brevis pollicis is usually inserted entirely into the proximal phalanx of the thumb, but it sometimes (21.2 p.c.) sends a slip to the extensor longus, and occasionally (6.8 p.c.) misses the proximal phalanx altogether, and is inserted into the terminal phalanx.

4. The extensor longus pollicis is always inserted into the terminal phalanx, but occasionally it may give or receive a slip to or from the extensor brevis. In some cases (5.4 p.c.) its tendon is double, while more rarely (2.3 p.c.) it is divided into three.

5. In 6.35 p.c. of all cases the extensor brevis pollicis is absent, while in 1.5 p.c. the extensor longus is wanting too.

¹ In one of these one slip passed through the same compartment of the posterior annular ligament as the extensor indicis.

QUESTION II.

The Popliteal Artery.

- (a) Its place of division.
- (b) The course of the anterior tibial artery in cases of high division.
- (c) The presence and point of origin of the posterior tibial recurrent and superior fibular branches.
- (d) The place of origin of the peroneal artery.

Replies have been received from the following gentlemen:—

Dr Low, Aberdeen University; Mr E. Williams Jones, Mason University College, Birmingham; Mr A. H. Capamagian, Owens College, Manchester; Dr Walter Graham, University College, Liverpool; Dr G. B. Mower White, University College, London; Mr E. J. Manning, St Mary's Hospital, London; Mr N. Navarra, Middlesex Hospital, London; Mr C. Nitch, St Thomas's Hospital, London.

(a and b) *The place of division of the popliteal artery.*—There are records of 106 observations, including those on the right and left sides. In 87 of these (82 p.c.) the artery divided at or within a quarter of an inch of the lower border of the popliteus muscle. In 7 cases (6.6 p.c.) it divided between a quarter and half an inch below the lower border. In 2 cases it divided more than half an inch below the lower border. In 1 case it divided between a quarter and half an inch above the lower border. While in 9 cases (8.5 p.c.) it divided more than half an inch above that point. The details of these 9 cases are as follows:—

1. Male.—Left side.—The popliteal artery divided at the upper border of the popliteus, the anterior tibial passed down behind the popliteus and pierced the membrane $\frac{1}{2}$ inch above the normal opening (which gave passage to the anterior tibial venæ comites). On the right side of the same body the bifurcation took place at the lower border of the popliteus.

2. Female.—Right side.—The artery divided $1\frac{1}{2}$ inches above the lower border of the popliteus. The course of the anterior tibial was normal. On the left side the artery divided opposite the lower border of the popliteus.

3. Male.—Left side.—The artery divided $1\frac{1}{2}$ inches above the level of the line of the knee-joint. The anterior tibial artery passed downwards on the popliteus muscle parallel with the posterior tibial artery. At the lower border of the muscle the artery was directed forwards in the usual manner. There is no observation of the right side of this body.

4. Female.—Right side.—The vessel divided into two branches at the level of the middle of the knee-joint: one of these was the posterior tibial, and the other a vessel which, at the lower border of

the popliteus, divided into anterior tibial and peroneal. The left side of the body is not described.

5. Female.—Left.—The popliteal artery divided into anterior and posterior tibial, 2·5 inches above the level of the lower border of the popliteus, or 0·4 inches above the line of the knee-joint. The anterior tibial artery passed down in front of the popliteus to the interval between the two heads of the tibialis posticus muscle. In its course it rested upon the posterior tibial recurrent artery. The condition of the opposite side is not mentioned.

6. Male.—Left.—The popliteal artery divided into anterior and posterior tibial, 0·8 inch above the lower border of the popliteus. The course of the anterior tibial artery was normal. The condition of the opposite side is not recorded.

7. Sex unknown.—Left.—The popliteal artery divided into anterior and posterior tibial, 2·2 inches above the level of the lower border of the popliteus, or 0·1 inch above the upper border of the tibia, and 1 inch above the upper border of the popliteus. The anterior tibial artery passed downwards in the popliteal notch of the tibia in front of the popliteus muscle, then downwards and slightly outwards on the popliteal surface of the tibia to the level of the neck of the fibula, at which level it disappeared between the heads of the tibialis posticus. The condition of the opposite side is not recorded.

8. Male.—Left.—The popliteal artery divided at the upper border of the popliteus, 0·5 inch below the upper border of the tibia, into anterior and posterior tibial. The anterior tibial was about twice as large as the posterior, and ran down on the posterior surface of the popliteus as far as the lower border, where it gave off the peroneal. On the right side the artery divided 0·3 inches below the lower border of the popliteus.

9. Male.—Right.—The artery bifurcated $\frac{3}{4}$ inch above the lower border of the popliteus, and $\frac{3}{4}$ inch below the level of the knee-joint. The anterior tibial passed downward and outward on the posterior surface of the popliteus until it reached the lower border; it then turned forward between the two heads of the tibialis posticus. On the left side the popliteal artery divided about $\frac{1}{16}$ th inch above the lower border of the popliteus.

A consideration of the above returns shows that in only two cases out of 106 (Nos. 5 and 7) did the anterior tibial artery pass in front of the popliteus. In case No. 4 there is some doubt as to the course of the artery, but we are of opinion that if it had passed in front of the popliteus the recorder would have mentioned the fact.

With regard to the influence of side, it will be noticed that 6 out of the 9 cases in which the artery divided more than half an inch above its normal point were on the left. If we take all the cases in which the artery divided a quarter of an inch or more above or below the lower border of the popliteus, we find that there were 10 on the right side out of 55 observations (18 p.c.), and 15 on the left out of 51 observations (29·4 p.c.). This seems to suggest that the point of

division of the popliteal artery is more likely to vary on the left side than on the right. Unfortunately, owing to the difficulty of observing every part in a dissecting-room, we have not always records of the two sides of each body; what we have, however, shows us that an abnormal point of division of the artery on one side is not very often coincident with a similar abnormality on the other.

With regard to sex, there are 64 observations of male legs; in 14 of these (22 p.c.) the artery divided a quarter of an inch or more above or below the lower border of the popliteus. There are 34 observations in females, and of these the artery was similarly abnormal in 8 (23.5 p.c.).

These figures point to the fact that sex plays no part in determining the frequency of the abnormality.

(c) The presence and point of origin of the posterior tibial recurrent and superior fibular arteries.

The posterior tibial recurrent artery was looked for in 103 legs, in 87 of which (84.5 p.c.) it was present.

On the right side it was present in 44 out of 55 observations (80 p.c.).

On the left side it was present in 43 out of 48 (90 p.c.).

Of the 87 cases in which the artery was present, it rose from the anterior tibial in 75 (86.2 p.c.), from the popliteal in 9 (10.4 p.c.), and from the posterior tibial in 3 (3.4 p.c.).

In many cases the posterior tibial recurrent rose by a common trunk with the superior fibular; these will be referred to later.

The point of origin of the vessel from the anterior tibial varies from the commencement of that artery to $\frac{3}{4}$ inch away; it usually comes off, however, about $\frac{1}{4}$ inch from the commencement of the anterior tibial.

In the two cases of high division of the popliteal in which the anterior tibial artery passed in front of the popliteus, the posterior tibial recurrent came off in one case from the posterior tibial recurrent with the superior fibular, and in the other case it was represented by two arteries rising from the anterior tibial while it was in front of the popliteus.

The superior fibular artery was looked for in 102 legs, in 87 of which (85.3 p.c.) it was present.

On the right side it was present in 45 out of 53 observations (84.9 p.c.).

On the left side it was present in 42 out of 49 (85.7 p.c.).

Of the 87 cases in which the artery was present, it rose from the anterior tibial in 51 (58.4 p.c.), from the posterior tibial in 16 (18 p.c.), from the popliteal in 9 (10.3 p.c.), from posterior tibial recurrent in 6 (6.8 p.c.), *vide supra*, from the inferior external articular in 2, from the peroneal in 2, while in one case the artery was double, one branch coming from the anterior and the other from the posterior tibial.

We have noticed in the returns examined that when the posterior

tibial recurrent and the superior fibular come off from the same vessel (not by a common trunk), the superior fibular is usually given off first.

In the two cases of high division of the popliteal in which the anterior tibial passed in front of the popliteus muscle, the superior fibular came off from a common trunk with the posterior tibial recurrent in one case, this trunk rising from the posterior tibial, while in the other case the superior fibular was absent.

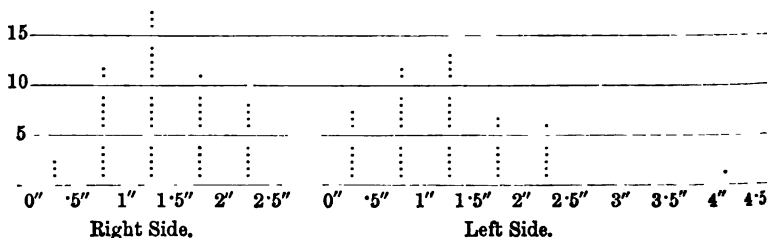
(d) *The place of origin of the peroneal artery.*—The peroneal artery may rise from the posterior tibial, from the anterior tibial, or the popliteal may trifurcate into anterior tibial, posterior tibial, and peroneal.

Out of 101 observations on both sides, the peroneal artery rose from the posterior tibial in 92 (practically 92 p.c.), the proportion being equal on the right and left sides.

In 5 cases out of the 101 the popliteal artery trifurcated, and this always took place at the lower border of the popliteus. The trifurcation occurred once out of 53 observations on the right side (1 p.c.), and 4 times out of 48 on the left (8 p.c.).

On four occasions the peroneal rose from the anterior tibial; except in one instance these were all in cases of high division of the popliteal; they occurred in cases Nos. 2, 3, and 9, already recorded. In the fourth case the popliteal artery divided at the lower border of the popliteus.

With regard to the point of origin of the peroneal artery, an average of the 101 cases gives us the following results. On the right side, it rose 1.27 inches below the lower border of the popliteus; on the left, 1.13 inches. In no case did it come off above the lower border of the muscle, while the lowest point of origin recorded was 4 inches below the lower border.



The above tables give the distance of the origin of the peroneal artery from the lower border of the popliteus in spaces of half an inch.

SUMMARY OF QUESTION II.

1. In 82 p.c. of all cases the popliteal artery divided at, or within a quarter of an inch of, the lower border of the popliteus.

2. In 8.5 p.c. it divided more than half an inch above that point.
3. In about 2 p.c. of all cases the anterior tibial artery passed in front of the popliteus.
4. The popliteal artery was more variable in its point of division on the left side than on the right.
5. Sex played no part in determining its variability.
6. The posterior tibial recurrent artery was present in 84.5 p.c. of all cases; it was rather more often present on the left side than on the right.
7. It usually came off a quarter of an inch from the origin of the anterior tibial, occasionally from the popliteal, rarely from the posterior tibial.
8. The superior fibular artery was present in 85.3 p.c. of all cases; it was rather more often present on the left than on the right.
9. In more than half the cases it rose from the anterior tibial, less frequently from the posterior tibial, popliteal, or, by a common trunk, with the posterior tibial recurrent.
10. The peroneal artery rose from the posterior tibial in 92 p.c. of all cases.
11. In 5 p.c. it rose from a trifurcation of the popliteal at the lower border of the popliteus.
12. In cases of high division of the popliteal, the peroneal often rose from the anterior tibial.
13. The commonest point of origin of the peroneal artery was between 1 and 1.5 inches below the lower border of the popliteus.

QUESTION III.

The Azygos Veins.

- (a) Their mode of origin in the abdomen or thorax.
- (b) Their communication—
 - (a) Between the azygos veins of the two sides.
 - (β) Between the azygos veins and the inferior vena cava, renal, and lumbar veins.

Reports upon the azygos veins were received from—

Messrs Bateman, St Thomas's Hospital; Dr Walter Graham, University College, Liverpool; B. H. St Claire Roberts, Mason University College, Birmingham; and N. Navarra, Middlesex Hospital.

The number of subjects examined—32—is not sufficient to form a basis for any definite conclusions, but the observations are worthy of record for the purposes of future observers, and because, so far as they go, they indicate the existence of a great variability in the number of communications which exist between the veins of the opposite sides of the thorax, and in the condition and extent of the azygos veins of the left side.

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Number of Cases Examined.	Male.	Female.	Sex unknown.
32 	25	6	1
Number of cases in which the vena azygos major commenced in the inferior vena cava,	16	11	4
			1

In 14 cases the level at which the vena azygos major arose from the inferior vena cava was noted. In 9 cases it was opposite the second lumbar vertebra, in 2 cases opposite the disc between the second and third lumbar vertebra, in 2 cases opposite the first lumbar vertebra, and in 1 case opposite the upper border of the third lumbar vertebra.

	Male.	Female.	Sex unknown.
Number of cases in which the vena azygos major commenced in the ascending lumbar vein,	16	13	3
			...
Number of cases in which the vena azygos minor inferior commenced in the left renal vein,	6	6	...
			...
Number of cases in which the vena azygos minor inferior commenced in the ascending lumbar vein,	24	16	7
			1
Number of cases in which the vena azygos minor inferior commenced in the lower part of the vena azygos major,	2	2	...
			...

In both of these cases the vena azygos major originated in the inferior vena cava.

	Male.	Female.
Number of cases in which the azygos veins of the left side formed a common trunk,	12	9
		3

Number of cases in which there were no communications between the vena azygos major and the veins of the left side,	1 male.
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In this case a common venous trunk commenced in the left ascending lumbar vein. It received all the posterior intercostal veins of the left side, and it terminated in the left innominate vein.

	Male.	Female.
Number of cases in which there was only one communication between the azygos veins of the right and left sides,	7	5
		2

In all these cases there was a single azygos vein on the left side, and the channel of anastomosis was situated at what appeared to be the point of union of the upper and lower left azygos veins.

The level of the anastomosing channel was variable. In 3 cases it was opposite the 8th thoracic vertebra, in 2 opposite the 9th thoracic vertebra, in 1 opposite the disc between the 8th and 9th thoracic vertebra, and in 1 opposite the 7th thoracic vertebra.

In one of these cases the two left azygos veins curved round the left side to the front of the aorta, and united in front of its right margin.

	Male.	Female.	Sex not stated.
Number of cases in which there were two communications between the azygos veins of the right and left sides,	10	8	1

In 4 of the 10 cases—3 male and 1 female—the two communications were from a common left azygos trunk. In all four cases one of the two communications was situated at what appeared to be the point of union of the upper and lower sections of the common trunk. In 2 of these cases, both male, the apparent point of junction was opposite the 8th thoracic vertebra; in 1, a female, it was opposite the 9th thoracic vertebra; and in 1, a male, opposite the 10th thoracic vertebra. In 2 cases, male, the second communication was above the apparent point of junction; and in the other 2, one male and one female, it was below that point. In the remaining 6 cases the two communicating channels were the vena azygos minor superior and the vena azygos minor inferior.

	Male.	Female.
Number of cases in which there were three communications between the veins of the left side of the thorax and the vena azygos major,	9	7

In one of the male cases the azygos minor inferior and superior opened separately into the azygos major, and the third communicating channel was from the azygos minor inferior below its main termination. In 3 male cases the three communications were with the superior left azygos vein, the 9th left intercostal vein, and the inferior left azygos veins. In all these cases the inferior azygos veins received only three tributaries, which were the last two left intercostal veins and the left subcostal vein. In 3 cases, 2 male and 1 female, the superior and inferior left azygos veins terminated in the right azygos vein, and the third vessel, which passed from the left to the right side, was the 7th left intercostal. In the female case the 7th left intercostal vein did not communicate with either the vein above it or the vein below it, but in one male case it anastomosed with the 8th intercostal before the latter terminated in the inferior left azygos vein, and in the other case it anastomosed with both the 6th and the 8th veins before they terminated in the superior and inferior left azygos veins respectively.

In one case, a female, the three vessels which joined the vena azygos major on its left side were the left superior intercostal, the vena azygos minor superior, and the vena azygos minor inferior.

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In one case, a male, the tenth and eleventh left intercostal veins opened separately into the vena azygos major, and the third vessel, which passed from the left to the right side, was a large trunk formed by the union of two stems, the lower of which received the eighth and ninth left intercostal veins, and the upper received all the left intercostal veins from the fourth to the seventh inclusive.

	Male.	Female.
Number of cases in which there were four communications between the veins of the left side of the thorax and the vena azygos major, }	2	1

In the male case, of the four vessels which crossed the vertebral column from the left side to join the vena azygos major, three were formed by the union of veins from two intercostal spaces; the lowest received the tenth and the eleventh intercostal veins, the second the eighth and ninth intercostal veins, the third the sixth and seventh intercostal veins, and the fourth was formed by the union of the third, fourth, and fifth intercostal veins.

In the female case the four vessels were the vena azygos minor superior, the vena azygos minor inferior, the seventh left intercostal vein, and the eighth left intercostal vein.

Number of cases in which there were five communications between the vena azygos major and the veins of the left side, }	2 males.
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In one case the veins passing directly from the left side to the vena azygos major were the left subcostal vein, the eleventh left intercostal vein, the tenth left intercostal vein, the vena azygos minor inferior, which crossed from left to right at the sixth thoracic vertebra, and the vena azygos minor superior, which crossed at the fifth thoracic vertebra. In the other case, the left subcostal vein and the eleventh and seventh left intercostal veins passed separately to the vena azygos major; the other two communications were the vena azygos minor inferior, formed by the union of the eighth, ninth, and tenth left intercostal veins, and the vena azygos minor superior, which formed a common trunk with the left superior intercostal vein, the two vessels constituting an anastomosing loop between the left innominate vein and the vena azygos major.

Number of cases in which there were six communications between the vena azygos major and the veins of the left side, }	1 male.
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The six communications were, the left first lumbar vein, the left subcostal vein, the eleventh, tenth, and ninth left intercostal veins, and the left vena azygos minor superior, which was also continuous with the left superior intercostal vein.

In the reports received, the number of communications between the vena azygos major and the veins of the left side is stated in every case, but the heights at which the communicating channels crossed

the vertebral column is omitted in some cases. In all, 79 communications between the vena azygos major and the veins of the left side were noted in 32 cases, and the height at which 75 of the communicating channels crossed the vertebral column is mentioned :—

21 crossed at the 8th thoracic vertebra, or at the disc above or below it.

12	"	9th	"	"	"
11	"	7th	"	"	"
9	"	10th	"	"	"
6	"	6th	"	"	"
5	"	11th	"	"	"
4	"	5th	"	"	"
3	"	12th	"	"	"
1	"	4th	"	"	"
2	"	disc between the 6th and 7th thoracic vertebrae.			
1	"	"	5th and 6th	"	"

Twenty-one communicating channels at the level of the eighth thoracic vertebra, or the disc above or below it :—

From common stem at apparent junction of its upper and lower parts,	6
From vena azygos minor inferior,	8
" " superior,	5
The eighth left intercostal vein separately,	1
From a trunk formed by the union of the eighth and ninth left intercostal veins,	1

Twelve communicating channels at the level of the ninth thoracic vertebra :—

From common stem at apparent junction of its upper and lower parts,	5
From vena azygos minor inferior,	3
The ninth left intercostal vein alone,	4

Eleven communicating channels at the level of the seventh thoracic vertebra :—

From vena azygos minor superior,	4
The seventh left intercostal vein alone,	4
From a common stem at the apparent junction of its upper and lower parts,	1
As a second communication from vena azygos minor superior,	1
From a trunk formed by the union of the seventh and eighth left intercostal veins,	1

Nine communicating channels at the level of the tenth thoracic vertebra :—

From vena azygos minor inferior,	4
The tenth left intercostal vein alone,	3

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From a common left azygos trunk at apparent junction between its upper and lower parts,	1
A common trunk formed by the union of the left tenth and eleventh intercostal veins,	1

Six communicating channels at the level of the sixth thoracic vertebra :—

From the vena azygos minor superior,	3
" " inferior,	1
From a common trunk formed by the union of the left sixth and seventh intercostal veins,	2

Five communicating channels at the level of the eleventh thoracic vertebra :—

From a common trunk below the apparent junction of its upper and lower parts,	1
The eleventh intercostal vein alone,	4

Four communicating channels at the level of the fifth thoracic vertebra :—

From the vena azygos minor superior,	3
The left superior intercostal vein,	1

Three communicating channels at the level of the twelfth thoracic vertebra :—

From the vena azygos minor inferior at its junction with the ascending lumbar vein,	1
From the commencement of the vena azygos minor inferior in the subcostal vein,	1
The left subcostal vein,	1

Two communicating channels at the level of the disc between the sixth and seventh thoracic vertebræ :—

The termination of the vena azygos minor superior,	2
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One communicating channel at the level of the fourth thoracic vertebra :—

The termination of the vena azygos minor inferior,	1
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One communicating channel at the level of the disc between the fifth and sixth thoracic vertebræ :—

The termination of the vena azygos minor superior,	1
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SUMMARY OF QUESTION III.

(1) In one half of the cases examined the vena azygos major was directly continuous with the inferior vena cava in the upper part of

the lumbar region; this is a point of interest in connection with Hochstetter's opinion that the lower part of the vena azygos major is not the remains of the right cardinal vein, but is a downgrowth from the upper part of that vessel. In the other half of the cases the vena azygos major was continuous below with the ascending lumbar vein. No communications were noted between the vena azygos major and the right renal vein.

(2) In the majority of the cases—24 out of 32—the vena azygos minor inferior commenced in the left ascending lumbar vein. In 6 cases it arose from the left renal vein, and in 2 cases from a stem common to it and the vena azygos major, which was connected with the inferior vena cava.

(3) In 12 out of 32 cases the azygos veins of the left side formed a continuous trunk.

(4) The number of communications between the azygos veins of the right and left sides varied from 1 to 6. Most commonly there were 2 communications, but 3 communications and only 1 communication were by no means infrequent.

(5) The level at which communicating channels between the azygos veins of the right and left sides cross the spinal column is very variable, but the most common situation is opposite the eighth thoracic vertebra.

(6) In only one case, a male, did the azygos veins of the left side pass in front of the aorta in their course to join the vena azygos major.

ARCHÆOLOGIA ANATOMICA.

II.

ATLAS AND EPISTROPHEUS.

THE history of the origin of the names of the several peculiar cervical vertebræ is shrouded in obscurity, and the early records of their application are peculiarly obscure and confused.

The first notices of such special names are given in the series of writings usually known as Hippocratic. 1. In the second book of *Epidemics*, now regarded as post-Hippocratic,—indeed, said by Galen to be the work of Thessalus, son of Hippocrates,—the author, when describing post-pharyngeal abscesses, alludes to their extending as far as τοῦ ὀδόντος καλούμενον ὅσπον (ed. Kuhn, iii. p. 441). He repeats this phrase a few lines below (p. 442), and says that this bone is not of the same shape in everyone. In another of the spurious Hippocratic books, the Treatise on the Nature of Bones, which, though ancient, is generally believed to be also post-Hippocratic in date, mention is made of the great vertebra (μέγας σφόνδυλος, Kuhn, i. 502–510). It is impossible from the context to make out with any degree of certainty in either case to what bones the names are applied, as there is not any note of position in either passage, but it is probable that the ὀδούς is the second vertebra, and that the great vertebra is the vertebra prominens.

Galen, in his treatise on the bones for beginners, calls the second vertebra ὀδοντοειδής, and its process πυρηνοειδής,¹ but he mentions the *odous* of Hippocrates as a synonym (ed. Kuhn, ii. 756, xvi. 681). See also his commentary on the *Prorrhetika* of Hippocrates.

Celsus (*lib.* viii. c. i.), while describing the vertebræ with fair accuracy, gives no names. Ruffus Ephesius (A.D. 100), in his

¹ In another place he says that it is named *pyrenoides* by the younger physicians, but *dens* by the ancients, and by Hippocrates himself (περί χρείας τῶν μορίων, xii. Kuhn, iv. 29).

book *περὶ ὀνομασίας τῶν τοῦ ἀνθρώπου μορίων*, in describing the parts of the neck, does not give any names to these bones, at least in Crassus' Latin translation, the only edition accessible to me here. It is probably, therefore, by mistake that the younger Riolan, in quoting him in his *Osteologia Norantiqua* (1626), says: "nam prima ab illis epistropheus secunda axon dicta fuit ex Ruffo Ephesio," iii. c. 2. In Crassus' edition of this chapter on the neck vertebræ there are no names given, but they may be in some other copy. This pair of names, however, occurs in the *Onomasticon* of Julius Pollux (ii. 130-132, ed. Dindorf); and it has been surmised by König (*Bibliotheca Vetus et Nova*, p. 707), and more recently by Jarneke, that Pollux has copied his notes on these bones from Ruffus (see Althaus, *Quæstionum de Julii Pollucis fontibus Specimen*, Berlin, 1874; and Jarneke, *Symbolæ ad Julii Pollucis Tractatum*, &c., Leipzig, 1885).

The whole passage in Pollux is worth translating, as it is the first place in which the names *Atlas*, *Epistropheus*, and *Axon* occur together:—"The neck (*τράχηλος*) lies below the head. It is also called *αὐχὴν* and *δειρή*, whence also *ὑποδερίς*, the lowest of these parts in front of the neck. The neck is set on seven vertebræ, which Homer calls *astragalos*,¹ and *sphondylium*,² the marrow which is in them. The vertebræ are also called *στροφές*, on account of the turning of the neck upon them, also *στροφίγγες* by Pherekrates.³ They stretch through the spine, bearing the marrow from the brain. This is both protected by membranes and supplied by nerves, and the whole system of these is called *γύης*. The first of the vertebræ, that turning with the neck, is called *epistropheus*, but Hippocrates also appears to call it *odous*. On the sides of it are two concavities, one on each side, into which two projecting processes, called the *coronai* of the head, beneath the occiput, are received. The second of the vertebræ, being immovable, is named *axon*. It has two processes, one on either side, the one articulating with the first vertebra, the other with the third vertebra. These are called

¹ See the description of the decapitation of Archilochus (*Il.* xiv. 466., and the death of Elpenor (*Od.*, x. 560).

² See the death of Deucalion (*Il.*, xx. 482-3).

³ Incert. 11 B. See also Plato, *Timæus*, 74, where it refers to all the vertebræ.

katochoi. The last of those arranged on these, being nearly equal to them, as the burden-bearer, is called the *atlas*.

In quoting this passage from Pollux, Riolan (p. 837) says:—"From this chapter you may learn that Pollux did not understand which vertebra Hippocrates called *odous*. It is not the first, but the second."

Vesalius, in commenting on this, remarks that the ὀδοντοειδὲς ὀδούς is not (ut Julius Pollux et Cælius,¹ dissectionum imperiti male recensent) the first, but the second; and he continues (p. 67), "porro jam duo apud Julium Pollucem nomina mihi succurrunt, quorum alterum primæ accommodat vertebræ, alterum secundæ, ac prima quidem *epistropheus*, secunda verò *axōn* ipsi nuncupatur. Hac nomina procul dubio à veteribus, qui pueros in Anatome exercebant, manarunt: hoc nomine volentes innuere vertebram, axis modo quiescentem, ac super quam alia circumvertitur: illo autem, vertebram quæ tanquam ad axem circumvolvitur. Atque id sanè meæ subscriberet sententiæ, qua caput super secundam in gyrum duci, jam sæpius asserui. Quòd verò à veteribus ante Galenum hæc nomina manarint, præter poetæ. Celsus mihi autor est,² qui tametsi ipsius codex ubi cervicis explicat vertebrae viciatus sit, atque ipse a se neutiquam intellecta multorum Galeni interpretum more verterit, attamen à veterum quopiam ex quo suum de ossibus Caput in latinam orationem convertit, eam sententiam primùm assumpsisse videtur, quæ meæ, atque ipsi denique veritati, proximè accedit."

In all this description, it will be noted, the name *atlas* does not occur, nor is it mentioned anywhere in the text of Vesalius' description; but on page 167, in describing the figure of the skeleton, he says, "Cæterum ab I ad K indicatur cervix, *τράχυλος*," (corrected in the table of errata), "*ἀνχὴν*, collum, (in Hebrew) zauor, gharron. Tenon athlas, quod nomen alii septimæ cervicis vertebræ duntaxat tribuunt" (Basel, 1543).

It thus appears that Vesalius adopts Pollux's application of these three names, *epistropheus* to the first vertebra, *axōn* to the second, and *atlas* to the seventh.

Among other old writers Theophilus (*cir.* A.D. 600) uses only

¹ I cannot find the passage in Cælius Aurelianus to which Vesalius alludes.

² This is to be taken as referring to the motions of the vertebra and head, not to the names, which are not given by Celsus.

the name *pyrenoides*, translated in the Latin version as *specillaris*, for the second vertebra (Crassus' transl. 1581, p. 80). Volcher Coiter,¹ writing in 1573, calls the first vertebra *atlas* or *epistropheus*; and Laurentius,² in 1600 (p. 89), says that the first vertebra is called by some *atlas*, by others *epistropheus*, on account of its turning.

Eustachius,³ writing about A.D. 1560, says: "Neque enim dicendum puto Galenum motum duarum primarum vertebrarum, aut ignorasse aut perperam tradidisse, ut ex veteribus Ruffus cum plerisque aliis fecit, qui solam primam vertebram capitis motum præbere, reliquas vero immobiles esse tradidit et ut quidam alii a quibus commutatis nominibus non sine errore prima vertebra, dicitur *athlas*, secunda a vertendo *epistropheus*, tertia a stabilitate *axōn*."

Here is a new nomenclature which is becoming more assimilated to modern usage, except in the case of the axis.

Jacobus Sylvius, in his *Liber Galeni de Ossibus*, 1561, mentions that Galen calls the dens *pyrenoides*, the condyles *corōne*, and that Hippocrates calls the second vertebra *odous*, but gives no other names. Realdus Columbus (*De re Anatomica*, 1559, Venice, lib. i. p. 49) describes the upper cervical vertebræ carefully, but gives no names.

Fallopian, who quotes Hippocrates and Pollux, gives as another name for the odontoid process, *morion conoeides*. He calls the first vertebra *epistropheus*, and the second *axōn*, "quasi quod prima habeat rationem rotæ: altera vero subjecta, id est, secunda habet rationem axis (*Expositiones in lib. Galeni de Ossibus*, Venice, 1606, p. 145). The famous Sicilian osteologist, Ingrassias, only adds as a synonym for the odontoid process the name *chelonoeides*, from its likeness to a tortoise's head; but does not give other names (*Comment. in lib. Galeni de Ossibus*, Palermo, 1603, p. 163). Spigelius also gives no distinctive names.

A large group of seventeenth century writers adopt the nomenclature referred to above by Eustachius, calling the first vertebra *atlas*, the second *epistropheus*, and the third *axōn*. This is found in Caspar Bauhin's *Theatrum Anatomicum* (1621, p. 257), St Hilaire's *Anatomie* (Paris, 1698, p. 38), Dionis (English

¹ *de Ossibus*.

² *de Ossibus*.

³ *Opuscula Anatomica*, Venetiis, 1563, p. 239.

trans. 1703), Blancard's *Anatomia Reformata* (1695), Verheyen (1699), and others. The last named author says, "credo nomen istud (axōn) per errorem a secunda vertebra ad tertiam fuisse translatum"; and Drake, in his *Anthropologia Nova* (1707, p. 663), says that the name *axis* is better suiting the office of the second vertebra, although, like the rest, he applies it to the third. Cheselden calls the first vertebra 'atlas,' as indeed does every author from the end of the seventeenth century to the present date. He names the second *dentata* in the early editions, *dentata* or *axis* in the later.

As a general rule, the German writers since the beginning of the eighteenth century have used *atlas* and *epistropheus* for the first and second vertebra, dropping the name *axis* or *axon*; while the French authors mostly use *atlas* and *axis*, dropping the name *epistropheus*. This is the case with Portal, Cloquet, Cruveilhier, Sappey, Testut, Poirier, etc. The English writers follow the French for the most part; a few only, such as Knox in his translation of Cloquet, using the name 'epistropheus.' Reviewing the literature of these names, I have little doubt that Vesalius was correct in his application of the name *atlas* to the seventh cervical vertebra.¹ It is the prominent point at the bend of the neck on which, in the classical figures, Atlas is supposed to bear the heavens.² In the figures of Atlantes from the Theatre of Dionysus, now in the Louvre (one of them is in the Stockholm Museum), this becomes evident, and the same will be seen in Cockerell's figure of the Atlas from the Temple of Olympian Zeus, at Agrigentum, as well as from the more modern Atlantes of Buonarroti and other masters. That this

¹ The transition is indicated by the elder Riolan in his *Anatomy* (Frankfort, 1611, p. 480), where he says of the lower cervical vertebræ, "reliquæ carent nomine excepta septem, quam nonnulli Atlantem malunt appellare, quia caput et reliquos spondylos sustinet, et inferendis ponderibus potissimum laborat." He himself, however, applies the name to the first vertebra, "quia ut Atlas Mathematicus cælum suis humeris gestare fungitur, ita hæc totum caput sustentat."

² The globe that Atlas bears is not the Earth, but one marked with the signs of the zodiac to represent the heavens. Homer says that "he upholds the tall pillars which keep earth and sky asunder" (*Odys.*, i. 52-58); and Hesiod says that "Atlas δ' οὐρανὸν εὐρὺν ἔχει κρατερῆς ὄψ' ἀνάγκης, ἐστῆός, κεφαλῇ τε καὶ ἀκαμάτῃσι χεῖρεςσι" (*Theog.*, 517, 519). It was a late error which led to the confusion of this celestial sphere with the earth. See Hermann, *Opuscula*, vii. p. 241; and Frazer, *Pausanias*, iii. 590.

was an old conception is shown not only by these examples, the first of which dates from the 3rd century B.C., but also by the description of *Atlantes* in Pausanias, as they occurred on the chest of Cypselus (v. 18. 4), and on the throne of Apollo at Amyclæ (iii. 18. 10; see also v. 11. 5 and vi. 19. 8). Unlike the *Caryatides*, the *Atlantæ* and their Roman equivalents, the *Telamones*, bore their burden on the neck, and so this idea of burden-bearing would naturally be associated by classical authors with the vertebra prominens; "non sine errore," therefore, is the first vertebra called *Atlas*, but the name is so firmly established that it would be pedantry to propose a change. In one of the metopes of the temple of Zeus at Altis, Olympia, Hercules has a cushion on his neck at the region of the 7th cervical vertebra, to bear the sky. (See, for fig. and references, Frazer's *Pausanias*, iii. 529.) Also in an antique figure in the Naples Museum, also representing Hercules as he relieved *Atlas* of his load for a time, the burden is borne in the same way.

In like manner, the mistaken application of the name *atlas* to the first, led to the further mistake of applying the name *epistropheus* to the second vertebra. The name means something which turns like a wheel upon an axis, as Fallopius has very well expressed; and those authors, like Bauhin, who speak of the second vertebra as *epistropheus* "a vertendo," certainly speak "non sine errore," and indeed the mistake is obvious from its rendering necessary the otherwise meaningless shift of the name *axis* to the third vertebra.

While, then, it is now too late to propose any alteration in the name of the first vertebra, it may be worth considering whether, in the revision of the international nomenclature, it might be possible to diminish this accumulation of errors by dropping the term *epistropheus*, and adopting that of *axis* for the second vertebra. It is a pity that this name, which originally belonged to the first vertebra, and was partly descriptive thereof, should be used in another sense for a bone to which it did not originally belong, and to which it is in no sense applicable. *Axis*, on the other hand, is shorter and more appropriate.

A. M.

ANATOMICAL NOTES AND QUERIES.

UNDER this head it is intended to publish, from time to time, short notes, detached observations, and other miscellaneous anatomical memoranda. A number of the leading Anatomists have promised to contribute paragraphs, and the help of all those engaged in anatomical work is solicited.

1. METHOD OF PREPARING LYMPHATICS FOR DISSECTION.—In the *Lancet* of June 18, 1898, Dr Cecil H. Leaf, Demonstrator of Anatomy at the London Hospital, recommends the forcing of a very large quantity of formalin solution into the blood-vessels, so that it is made to pass through the capillaries into the areolar tissue, and thence either into or around the lymphatics, as an easy method of rendering these vessels distinct. By this method he has demonstrated the existence of communication between the inguinal lymphatic vessels and the branches of the superficial circumflexa ilii vein. By permission of the proprietor of the *Lancet*, Dr Leaf's figures are reproduced here to indicate the kind of communication which he has found.

Another paper on the lymphatic system, entitled "Morphologie et Développement du système lymphatique," by Ranvier, is published in the *Archives d'Anatomie Microscopique de Paris*, i. p. 125.

2. TOPOGRAPHY OF THE ABDOMINAL VISCERA.—Formalin has been employed by Professor Addison, of University College, Sheffield, in his elaborate researches in this department. By the use of long steel pins driven at definite points into the abdominal wall through the cavity, and into the table beneath, he has made a definite survey of the position of the viscera in a large number of fresh subjects. In a paper published in the "Commemoration Volume" of University College, Sheffield, he has given a summary of his method and some of his results,

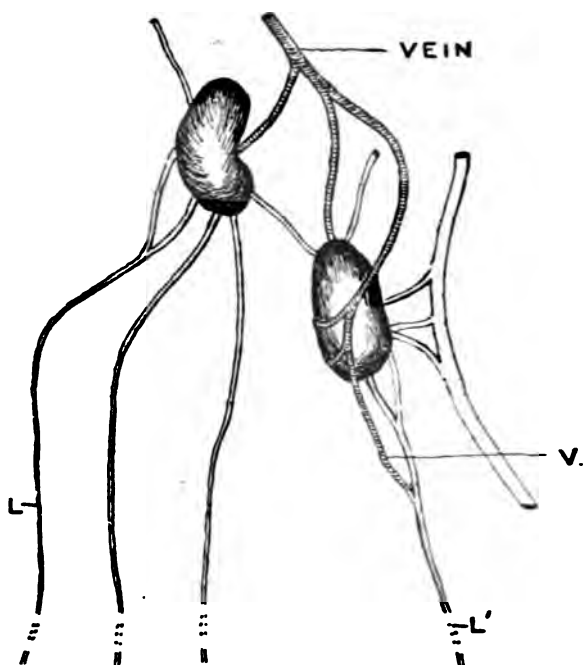


FIG. 1.—Dissection showing two of the femoral glands, with their lymphatic vessels and veins.

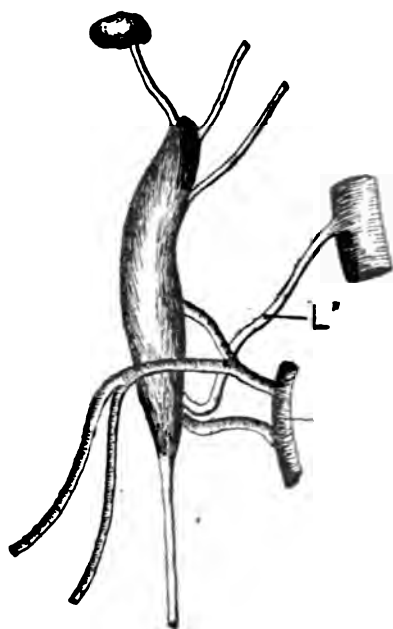


FIG. 2.—Dissection of a femoral gland, showing a lymphatic vessel (L) terminating in a vein.

which are highly instructive, especially as regards the stomach-bed and the movements of the pylorus. It is to be hoped that the results of this most laborious piece of work will be published *in extenso* and adequately illustrated, as they form an important contribution to this most practical department of applied anatomy.

Another article of interest on a cognate subject is on "The Surgical Applied Anatomy of the Rectum," by Taylor, in the *Transactions of the Royal Academy of Medicine of Ireland*, xv. p. 451.

3. THE GREAT OMENTUM.—Professor Adami, of McGill University, Montreal, has published in *The Philadelphia Medical Journal* for 26th February 1898 an interesting paper on this neglected structure, in which he refers to it as "the ominous organ." It is tempting to correlate omen and omentum; but, as Dr Still pointed out in a learned paper some years ago (I have unfortunately lost the reference), there is no etymological connection between the words. Professor Adami discusses a number of points as to the disposition and functions of this membrane, and lays stress on its vascularity and richness in lymphatics, as suggestive of some connection with the secretion and absorption of peritoneal fluid.

4. SUPRACONDYLAR PROCESS IN THE CHILD.—The earliest appearance of this process known to me is shown in a specimen in the Cambridge Museum. The humerus is that of a child 27 months old. It measures 105 mm., and the process is 3 mm. long, and both it and the faint ridge above are ossified. The nucleus of the capitellum has appeared, but none other of the lower epiphysial centres. I should be glad to have some reference to the fetal condition of the process, whether represented by a cartilaginous or periosteal prominence, before ossification.

5. MULTIPLE CENTRES OF OSSIFICATION IN THE ACROMION.—In vol. xxvii. of *this Journal*, plate xv., there is a figure of an acromion with multiple centres of ossification. A specimen remarkably like it was long ago figured by Vesalius (Basel edition, p. 5) showing centres. Subsequent writers seem to

have taken as little notice of the latter as the recent authors have done of the former specimen.

6. POLISH CRANIA.—The paper by M. Tschaussow, of Warsaw, on this subject (*Anatomischer Anzeiger*, vol. xiv. No. 24), deals chiefly with the premature synostosis of sutures which seems to be characteristic of these, as it is also of other Slavonic skulls (Mitrof, Fortunatow, etc.). He notes also the dependence of the digital depressions on the inner table of the skull on the weight of the brain rather than on general cranial constraint. He finds the average capacity of the adult Polish skulls to be 1468 c.cm. in males and 1328 in females, and the cranial index 81.6 in males and 79.45 in females, thus agreeing closely with other Slavonic averages.

7. MODE OF POST-EMBRYONAL GROWTH OF MUSCLES.—In the *Anatomischer Anzeiger*, xiv. p. 619, Meek records some suggestive observations on this subject deduced from the study of the limb muscles of field-mice, rats, and cats of different ages, and concludes that muscles grow post-embryonally by hypertrophy of the fibres, while there is a diminution in the actual numbers of the fibres. In cats he found that for every fibre present in the biceps brachii at 240 days there were 2.2 fibres at 9 days, while the fibres of the former were in sectional areas to those of the latter as 6:1; and the areas of the cross-sections of the muscle at these stages were as 1:0.373. The author does not state the number of specimens from which these remarkable results are deduced; and while his observations seem to establish the general fact of numerical reduction with growth, the rate of reduction is probably as variable as is the initial number of fibres in the muscle at birth.

8. DESCRIPTIVE ANATOMY AT THE ANATOMISCHE GESELLSCHAFT, KIEL, 1898.

Four interesting groups of communications were made to this meeting. Prof. Pitzner, of Strassburg, read papers on brachyphalangia (p. 18), hyperphalangia (p. 20), and on the inferior tibio-fibular joint. In the last he correlates the tibio-fibular ligamentous facet described by Fawcett, the rudimental

or spurious inferior tibio-fibular joint, and the change in position of the os trigonum in course of growth, and regards the latter change as productive of structural alterations in the joint.

Dr Mehnert, of Strassburg, communicated two papers, one on the form-variations of the cesophagus (p. 201), and a second on the variations in position of the thoracic aorta.

Dr Eisler, of Halle (p. 241), discussed the causation of the linea semicircularis Douglassii, and examined the grounds of the hypotheses of Gegenbaur and Solger. He shows the relation which exists between the development of this line and the processus vaginalis peritonæi traversing the deep abdominal ring.

Dr Hultkrantz, of Stockholm (p. 248), studies the condition of surface-tension of the articular cartilages, using the method which Langer has employed to determine the lines of tension of the skin, viz, the changes which take place in the forms of perforations made with a round awl, and the directions assumed by the slits into which these round holes become altered; on the head of the radius these radiate from the centre of the bone, on the trochlea humeri they are transverse to the surface, on the patella they are mostly vertical except along the inner border, on the lower end of the femur they radiate from the outer condylar notch, etc. All these papers are valuable additions to descriptive human anatomy.

Journal of Anatomy and Physiology.

THE CONVOLUTIONS OF THE CEREBRUM OF THE HORSE. By O. CHARNOCK BRADLEY, *Lecturer on Anatomy, New Veterinary College, Edinburgh.*

ANYONE who has had occasion to consult works on veterinary anatomy must have been struck with the discrepancies in the various descriptions of the fissures of the horse's brain. These discrepancies cannot be attributed to any scarcity of literature on the subject; for, though somewhat scattered, references are fairly numerous.

Serres (1), in 1824, gave a drawing of the horse's cerebrum, but unfortunately the attainment of artistic curves seems to have been more sought after than a true representation of the fissures as they actually exist. We do not, therefore, derive much help from this source.

Leuret (2), in his classic work, places the horse in the ninth of the fourteen groups into which he divides mammals according to the degree of development of the cerebral convolutions. His atlas contains three figures of the horse's brain, which, on account of their accuracy, must have been of inestimable value to subsequent workers. One fissure alone is named, this being the fissure of Sylvius. The four chief arcuate convolutions are named numerically, and supra-orbital convolutions are indicated.

P. Broca (3) names the fissures and convolutions, and illustrates his statement with two figures.

Krueg's (4) well-known investigations on the fissures of the brain of the Ungulata include observations on six horses and two donkeys. The fissures of the horse's brain are, conse-

quently, very fully discussed, three figures being employed by way of illustration.

Dareste (5) and Owen (6) have both added considerably to the literature on this subject.

McFadyean (7), in his *Dissector's Guide to the Anatomy of the Horse*, in describing the brain, employs a nomenclature almost entirely his own.

Sir Wm. Turner (8), in his address delivered before the Anatomical Section of the Tenth International Medical Congress, briefly describes the horse's fissures and convolutions, and gives two figures in illustration.

Chauveau and Arloing (9), in their exhaustive treatise on the *Anatomy of the Domestic Animals*, have sought to establish a parallel between the convolutions and fissures of the horse and of man. They therefore employ names borrowed from human anatomy.

Ellenberger (10) is, so far as I am aware, the latest writer who has added to the literature of the subject. He shows a strong leaning towards the nomenclature employed by Krueg, though he does not slavishly follow his predecessor.

The above cannot be considered an exhaustive list, but is sufficient to show that many writers in different languages have added their quota to our knowledge of the subject.

For some time past I have sought to put the descriptions of the various writers to the test by comparing them with the actual brain of the horse. The more one makes such comparison, the more one sees room for addition, and, to a less degree, for correction. I concluded, therefore, that some slight service might possibly be rendered to comparative anatomy by giving the results of my observations so far as they have gone. A considerable number of adult hemispheres have been examined, as well as hemispheres from foetuses of various ages. It is hoped that when more embryological material has been examined, something may be said concerning the time and sequence of appearance of the various fissures. So far, however, the amount of material at my disposal has not been sufficient to allow of any definite and complete statements being made.

Seeing that the convolutions of the horse's cerebrum are arranged in four tiers, as in the dog, it seems not irrational to employ

the nomenclature suggested by Sir Wm. Turner (11) in his description of the brains of some Carnivora, and now very generally adopted. The brain of the horse being more complicated in its fissures than the same organ of the dog, a few additional names will be necessary.

The rhinencephalon of the horse is marked off from the pallium by the customary fissures.

The *rhinal* and *post-rhinal fissures* differ very materially in point of depth: the former is shallow, whereas the latter is relatively very deep. The post-rhinal fissure, when traced backwards, is found to terminate on the tentorial surface of the hemisphere, but does not join the calloso-marginal fissure.

The *dentate* or *hippocampal fissure*, as usual, forms the inner boundary of the hippocampal lobe. The fissure is of no great depth, and, moreover, becomes much shallower at its upper extremity.

The surface of the hippocampal lobe is marked by one, sometimes two longitudinal fissures running parallel to the post-rhinal fissure.

I. CRANIAL SURFACE OF THE PALLIUM.

The four-tier arrangement of the convolutions being most clearly marked in the posterior part of the hemisphere, it will be found most convenient for descriptive purposes to divide the cranial surface of the pallium into anterior and posterior portions by a line joining the crucial fissure with the anterior limb of the fissure of Sylvius. This is practically the line used by Leuret for the purpose of dividing the convolutions into anterior and posterior. In this division the convolutions below the anterior limb of the fissure of Sylvius are counted as being anterior.

(a) *Posterior Part of the Cranial Surface.*

In describing the *Sylvian fissure*, it is perhaps best to consider it as consisting of two limbs, thus following the example of Krueg. The vertical limb is short and transverse. The anterior limb is much more conspicuous and of much greater length. It runs forwards and slightly upwards, and from its direction

appears to be the forward continuation of the post-rhinal fissure. In some specimens this limb appears to be much longer than usual, because of its joining a fissure described and figured by Ellenberger under the name of *diagonal*.

The fissure I would describe under the name of *supra-sylvian* has received little attention at the hands of recent investigators, though both Leuret and Broca figured it. Leuret, in particular,

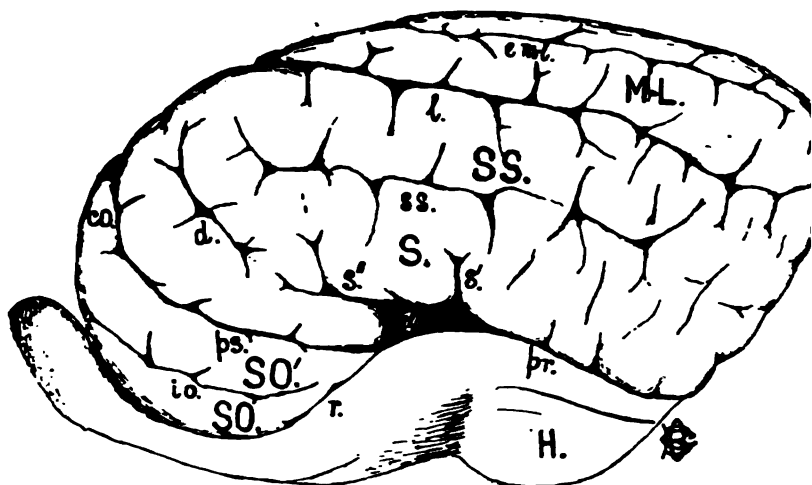


FIG. 1.—Lateral view of left hemisphere of adult horse.

attached importance to it, inasmuch as he indicated it as separating convolutions I and II. Its early appearance in the foetal brain adds to its claim to be considered as a fissure of some moment (fig. 2, ss). This, in conjunction with its comparative depth in the adult, will justify the attention here paid to it.

In the foetus this fissure consists, during the earlier stages of its development, of two segments; a condition which may be preserved for some time after birth, or even into adult life. In the adult the segmented character is usually not apparent on superficial examination, but is revealed by separating the adjacent convolutions.

The *lateral fissure* is one of the deepest on the cranial surface of the hemisphere. Its anterior extremity is on a level with

a short and inconstant fissure, which the majority of authorities seem to regard as corresponding to the crucial fissure of the Carnivora. From this point the lateral fissure extends backwards and outwards, and finally terminates near the boundary of the tentorial surface. Anteriorly it is continuous with the coronal fissure, and partially on this account I have ventured to use the

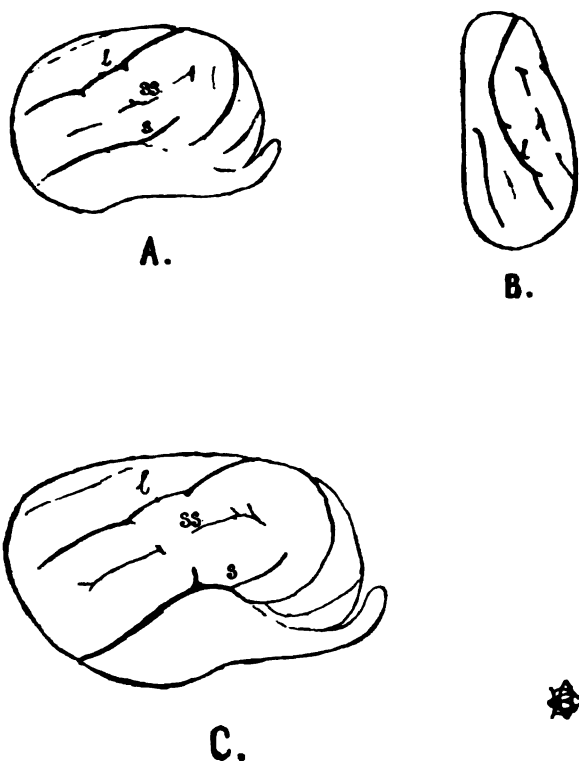


FIG. 2.—A, lateral view of right hemisphere of 129 days fetal mare. B, superior view of the same. C, right hemisphere of 5 months fetal horse.

name of *lateral* to designate it, in spite of the fact that Krueg, Owen, and Ellenberger have called it supra-sylvian. Chauveau looks upon it as corresponding to the Rolandic fissure of Man.

The *medio-lateral fissure* runs very nearly parallel to the great longitudinal fissure which separates the two cerebral hemispheres. It commences at a point slightly posterior to the so-called crucial fissure, and proceeding backwards, with a slight

inclination outwards, it may reach the tentorial surface, though this is not usual. Its depth is considerable, sometimes equalling, and indeed in some specimens exceeding, that of the lateral fissure. Krueg and Ellenberger call this fissure *lateral*, while Owen used the name *lambdoidal*.

The *Sylvian* and *supra-sylvian convolutions* are simple in their arrangement, and seldom complicated by the presence of subsidiary fissures. Not so the medio-lateral and marginal convolutions.

The *medio-lateral convolution* is almost invariably complicated by an antero-posterior fissure which runs parallel to the medio-lateral, being in some instances as long as this latter fissure. This minor fissure has been figured by Leuret, Krueg, Owen, and Ellenberger. No name has been assigned to it by Leuret or Krueg, but Owen has called it *medi-lateral*, and Ellenberger *ecto-lateral*. In order to bring it in line with the names suggested above, it might be called the *ecto-medio-lateral fissure*. The two secondary convolutions into which the medio-lateral gyrus is thus divided are usually, in their turn, indented by inconstant furrows, whose general direction is longitudinal.

The *marginal convolution* follows the lead of the medio-lateral in being divided into two parallel parts by a longitudinal fissure, which might be named *endo-medio-lateral*. This fissure commences behind the crucial fissure, and is continued on to the tentorial surface; the whole of its length is marked by extreme simplicity.

(b) *Anterior Part of the Cranial Surface.*

The anterior part of the cranial surface consists of an orbital surface and an area surmounting this.

The orbital surface contains olfactory and intra-orbital fissures, with straight, internal supra-orbital and external supra-orbital convolutions.

The *olfactory fissure* is always shallow, and not very constant in its constitution, being sometimes double.

The *intra-orbital fissure* exhibits some variations in the mode of termination of its posterior extremity. Three variations have been met with. First, it may join the rhinal fissure; secondly,

it may join the præ-sylvian; and thirdly, it may join neither. It is difficult to say which is most common.

In some instances the intra-orbital fissure appears to be continuous with the rostral fissure of the mesial surface; in these cases, however, a hidden convolution will always be found.

The gyrus rectus and internal supra-orbital convolution are

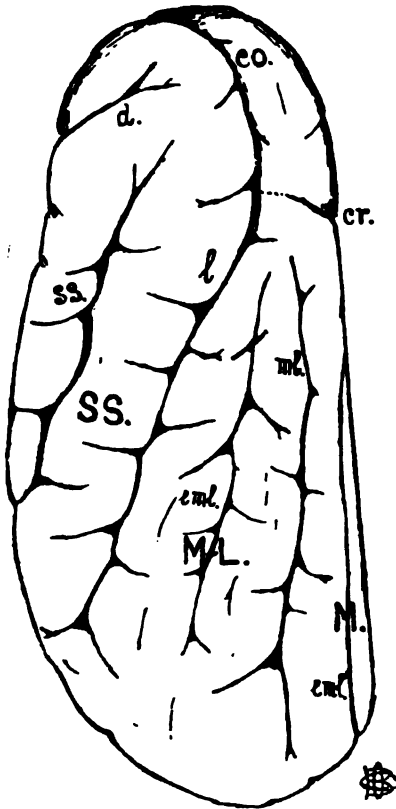


FIG. 3.—Upper surface of left hemisphere of horse's brain.

always continuous with each other around the anterior extremity of the olfactory fissure.

The *præ-sylvian fissure* forms a connecting link between the rhinal fissure below and the coronal fissure above. It is quite impossible to say where the præ-sylvian ends and the coronal begins.

The *coronal fissure* joins the anterior end of the lateral fissure. The præ-sylvian, coronal, and lateral fissures are always continuous, and always of great depth, so that they form a long curved indentation, which at once strikes the eye of an observer.

The *diagonal fissure* runs parallel to and at no great distance from the imaginary line which has been used to divide the cranial surface of the hemisphere into anterior and posterior areas.

What exactly in the horse corresponds to the insula of man seems to be somewhat doubtful. So far as I am aware, Clark

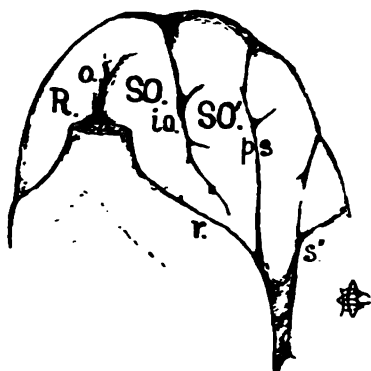


FIG. 4.—Orbital surface of left hemisphere of horse's brain.

(12) has made the latest statement. He has examined five equine brains, and has concluded that the insula consists of a variable number of 'gyres' included between the rhinal fissure and the posterior part of the anterior limb of the fissure of Sylvius. This area is indicated in fig. 1 by deep shading. Usually (as shown in the figure) two small eminences can be seen in this position without opening up the fissures. Clark quotes Lussana and Lemoigne (13) as stating that the insula of the horse is of considerable size. Further observation appears to be necessary before arriving at any definite conclusion.

II. MESIAL SURFACE OF THE PALLIUM.

The two chief convolutions—marginal and callosal—on this surface are separated by a deep and continuous *calloso-marginal*

fissure, which begins anteriorly on a level with and below the anterior extremity of the corpus callosum, and ends on the tentorial surface. The depth of this fissure is not uniform, the anterior portion (corresponding to the genual fissure of the dog) being much deeper than the posterior portion (splenial fissure of the dog).

The marginal convolution is indented by a so-called *crucial fissure*, which may appear to join both calloso-marginal and lateral fissures; on careful examination, however, hidden convolutions will always be found. The hidden convolution on the cranial surface may be considered as representing the sigmoid gyrus of Carnivora.

A *rostral fissure* extends from the margin of the anterior and

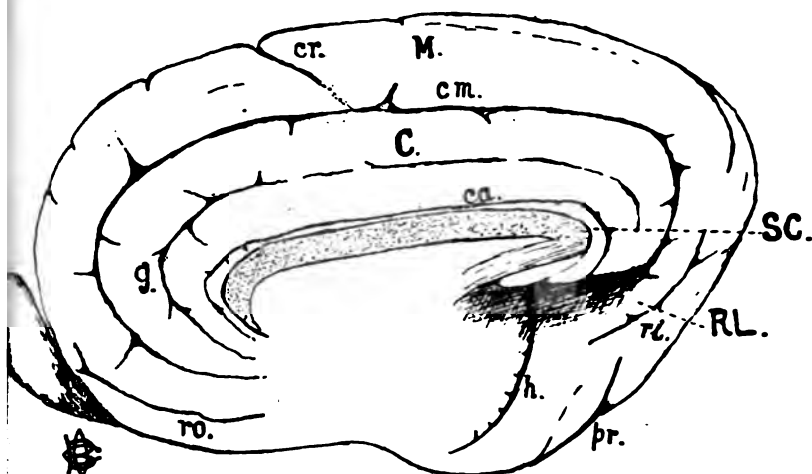


FIG. 5.—Mesial and tentorial surfaces of right hemisphere of horse.

inferior part of the mesial surface to a level with the genu of the corpus callosum.

The callosal convolution is never perfectly simple, but always possesses a longitudinal fissure, which may be continuous, but is more commonly composed of two or more segments. The anterior part of this fissure is the deepest and most constant, and has been called the *genual fissure* by Krueg, whose example has been followed by Ellenberger. If it be admitted, however,

that the calloso-marginal fissure corresponds to splenial and genual fissures, obviously the view of Krueg is incorrect.

Although the fissure in the callosal convolution has been figured by Leuret, Broca, Turner, and others, a name has not been bestowed upon it by them. Perhaps the term *intra-callosal* might not be entirely inappropriate.

A distinct *supra-callosal convolution* may always be found in the callosal sulcus. It bends round the genu of the corpus callosum in front and the splenium behind, being continuous with the fascia dentata. Its presence seems to have been overlooked, probably on account of its variable size, though in some instances it is sufficiently conspicuous.

The callosal sulcus is continuous with the hippocampal fissure. This becomes obvious if the hippocampal fissure be traced upwards; its depth has decreased considerably on reaching the splenium, and the furrow connecting the hippocampal and callosal fissures may in some cases be little more than a suggestion. This probably explains why previous writers have overlooked the connection.

III. TENTORIAL SURFACE OF THE PALLIUM.

On this surface the posterior extremities of the post-rhinal and callosal-marginal fissures form the most conspicuous depressions. These fissures are never continuous in the horse, a definite retro-limbic gyrus intervening. An oblique fissure, which might be called retro-limbic, always indents this bridging convolution.

RELATIVE DEPTH OF THE FISSURES.

In estimating the relative depth of the various fissures, it was found that, in order to obtain reliable results, transverse sections were necessary. In the following list the figures are to be taken as of relative value only, as in all the specimens examined hardening had previously been resorted to.

As was anticipated, the depth was found to vary relatively in different brains, and even in the two hemispheres of the same brain. This made the task somewhat difficult, and no doubt more extended observation would to some extent change the following list:—

	Depth.
Coronal fissure,	16 mm.
Lateral fissure,	12 "
Calloso-marginal fissure,	} 11 "
Post-rhinal fissure,	
Sylvian (anterior limb) fissure,	} 10 "
Medio-lateral fissure,	
Præ-sylvian fissure,	} 9 "
Supra-sylvian fissure,	
Diagonal fissure,	8 "
Ecto-medio-lateral fissure,	7 "
Ento-medio-lateral fissure,	6 "
Intra-orbital fissure,	} 5 "
Rostral fissure,	
Rhinal fissure,	3 "
Intra-callosal fissure,	} 2 "
Olfactory fissure,	

The figures speak for themselves, and therefore no comment is necessary.

It is interesting to notice that the crucial fissure was so variable in its depth that it was thought advisable to exclude it from the above list. In one instance its depth was only 5 mm., whereas in another it reached 13 mm.

The subjoined list gives the chief synonyms employed by various writers to denote the different fissures, and will probably be found of use in comparing their descriptions.

Fissures.	Kruog.	Owen.	Ellenberger.	Chauveau.	M Fadyean.
Sylvian. Vertical limb. Anterior limb. Supra-sylvian.	Sylvian. Proc. acuminis. " anterior.	Sylvian. ...	Sylvian. Proc. acumin. " antet.	Sylvian (i). ...	Sylvian.
Lateral. Medio lateral. Ecto-medio-lateral. Ento-medio-lateral.	Supra-sylvian Lateral. ...	Supra-sylvian. Lambdoidal. Mediolateral. Endo-lambdoidal.	Supra-sylvian. Lateral. Ecto-lateral. Ento-lateral. Diagonal. Pre-sylvian.	Rolandic. ...	Great oblique. ...
Diagonal. Pre-sylvian. Coronal. Rhinal. Post-rhinal.	Diagonal (?). Pre-sylvian Coronal. Rhinal.	...	Diagonal. Pre-sylvian. Coronal. Rhinal. Post-rhinal.	...	Lateral (?). ...
Olfactory. Intra-orbital. Calloso-marginal. Rostral. Crucial.	...	...	...	Sylvian (t). Olfactory.	Sylvian. ...
Intra-callosal. Hippocampal. Retro-limbic.	Splenic. Rostral. Crucial. Genual. Hippocampal. ...	Marginal (?). Frontal. Supra-callosal. Hippocampal. ...	Calloso-marginal. Rostral. Cruciate. Genual. Post-splenic. ...	Calloso-marginal. Crucial. ...	Calloso-marginal. Crucial. ...
					Hippocampal. ...

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- (2) LEURET, *Anatomie comparée du Systeme Nerveux*, 1839-57.
- (3) P. BROCA, "Anatomie comparée des circonvolutions cérébrales," *Revue d'Anthropologie*, 1878, figs. 14 and 22.
- (4) KRUEG, "Ueber die Furchung der Grosshirnrinde der Ungulaten," *Zeitschr. f. Wissensch. Zoologie*, xxxi., 1878.
- (5) DARESTE, "Troisième mémoire sur les circonvolutions du cerveau chez les mammifères," *Annales d. sci. naturelles*, 4^{me} serie, *Zoologie*, t. iii.
- (6) OWEN, *Anatomy of the Vertebrates*, vol. iii., 1868.
- (7) M'FADYEAN, *Anatomy of the Horse*, 1884.
- (8) TURNER, "The Convolution of the Brain," *Jour. of Anat. and Phys.*, vol. xxv., 1890.
- (9) CHAUVEAU and ARLOING, *Traité d'Anatomie comparée des Animaux domestiques*, 4^{me} édition, 1890.
- (10) ELLENBERGER and BAUM, *Topographische Anatomie des Pferdes*, 1894.
- (11) TURNER, *Jour. of Anat. and Phys.*, vol. xxii. p. 580.
- (12) CLARK, "Comparative Anatomy of the Insula," *Journal of Comparative Neurology*, vi., 1896, p. 59, figs. 24 and 25.
- (13) LUSSANA and LEMOIGNE, *Fisiologia dei centri nervosi Encefalici*, 1871.

EXPLANATION OF REFERENCE LETTERS IN FIGURES.

Fissures:—*s'*, vertical limb of Sylvian fissure; *s''*, anterior limb of same; *ss*, supra-sylvian; *l*, lateral; *em-l*, ecto-medio-lateral; *em-l*, ento-medio-lateral; *d*, diagonal; *co*, coronal; *ps*, præ-sylvian; *cr*, crucial; *o*, olfactory; *io*, intra-orbital; *r*, rhinal; *pr*, post-rhinal; *cm*, calloso-marginal; *ca*, callosal; *ro*, rostral; *rl*, retrolimbic; *h*, hippocampal; *g*, intra-callosal.

*Convolution*s:—*S*, sylvian; *SS*, supra-sylvian; *M-L*, medio-lateral; *M*, marginal; *C*, callosal; *SC*, supra-callosal; *R*, gyrus rectus; *SO*, internal supra-orbital; *SO'*, external supra-orbital; *RL*, retrolimbic; *H*, hippocampal lobe.

ON THE EYELID-MUSCLES OF THE CARCHARIIDÆ
AND SCYLLIUM: A CONTRIBUTION TO THE MORPHOLOGY
OF THE NICTITATING MEMBRANE OF SHARKS. By W. G.
RIDEWOOD, D.Sc., F.L.S., *Lecturer on Biology at St Mary's
Hospital Medical School, London.*

THE presence of a horizontal duplicature of the skin below the eye in *Scyllium* has often suggested to me the possibility of a nictitating membrane, similar to that of *Galeus* or *Mustelus*, being here in process of evolution. The fold is not very strongly marked, and does not actually overlap the lower eyelid (which, according to this view, would have to be regarded as the nictitating membrane), but the relations are such as might reasonably be supposed to occur during the early stages of evolution of the third eyelid. There is good ground for belief that the most recently evolved eyelid of such a fish as *Mustelus* is the lower eyelid, the primitive lower eyelid having become the nictitating membrane, and it appeared to me that in this duplicature of skin in our common dogfish (*Scyllium*) there was evidence of a transient condition, which, in course of time, might result in the evolution of as complete a nictitating apparatus as occurs in *Mustelus*.

On referring to the literature on the subject, I found an original statement by Hubrecht (2, p. 100) to the effect that the *musculus nictitans* occurs not only in the sharks provided with a nictitating membrane, but also in *Scyllium* and *Pristiurus*. This served to show that the matter was of more than ordinary interest, and I commenced forthwith to investigate the eyelid-muscles of *Scyllium*, with the object of determining how far these agreed in structure and arrangement with those of the Carchariidæ. But, as frequently happens, the investigation could not be kept within the prescribed limits. The meagre state of our knowledge of the muscles of the eyelids of the Carchariidæ rendered necessary a minute personal examination of these; and the inquiry then extended itself further to the examination of the superficial constrictor muscle of the spiracle, which in some cases becomes so involved with the above muscles that, in dealing with them,

its study cannot well be neglected. Thus the investigation finally resolved itself into a comparative study of the muscles of the eyelids and spiracle in *Scyllium* and five representative genera of the Carchariidæ.

The species examined were *Scyllium canicula* and *Scyllium stellare* (catulus), *Carcharias laticaudus*, *Carcharias acutus*, *Galeus canis*, *Zygæna tudes*, *Triacis semifasciata*, and *Mustelus vulgaris*. The specimens of *Carcharias* were foetal, that of *Zygæna* young, and those of *Galeus*, *Triacis*, *Mustelus*, and *Scyllium* adult. The *Galeus*, *Mustelus*, and *Scyllium* were obtained by purchase from various localities on the South Coast of England. For the remainder of the material I am indebted to the kindness of Mr G. A. Boulenger, F.R.S., of the Natural History Museum, and Prof. Charles Stewart, F.R.S., of the Royal College of Surgeons' Museum.

According to Joh. Müller (6, p. 120) the presence of a nictitating membrane in some sharks and its absence in others was first observed by Rondelet in 1554. The occurrence of a special muscle in connection with the nictitating membrane was made known by Müller himself in 1839 (4, p. 52): and in that excellent systematic memoir by Müller and Henle (5) published two years later, the membrane was shown to be present in all the genera of the families Carchariæ, Triænodontes, Galei, Scylliodontes, and Musteli. Shortly afterwards, Müller published figures of the nictitating membrane and its muscle in *Mustelus*, *Carcharias*, and *Zygæna*, together with a page and a half of explanatory text (6, pl. 5, figs. 1-3, pp. 121-122).

Humphry's paper on the muscular anatomy of *Mustelus* (3) added nothing to our knowledge of the eyelid-muscles of this genus; and Vetter's investigation (9) being confined to the genera *Heptanchus*, *Scymnus*, and *Acanthias*, has only an indirect bearing on the subject. Many valuable observations on the muscles of the spiracle and eyelids occur in Hubrecht's chapter on the musculature of elasmobranch fishes in Bronn's Thier-Reich (2), and it is greatly to be regretted that this author has been prevented from fulfilling his intention (2, p. 100, footnote 2) of giving a complete account of the nictitating apparatus in the chapter to have been devoted to the sense organs of fishes.

Tiesing (8) has recently furnished a detailed account of the

eyelid-muscles of *Mustelus*, and Allis (1) has recorded some observations on the same muscles in *Galeus*. The muscles of the spiracle and eyelids of *Mustelus* are shown incidentally in figures 5 and 8 of Ruge's important work on the distribution of the facial nerve in Vertebrates (7). No special description of these muscles is given in the text, since they do not come within the scope of the paper, but the accuracy of their delineation shows with what great care the dissections had been made.

As already pointed out by Müller, the nictitating membrane is best developed in *Carcharias*, in which genus it is capable of covering nearly the whole of the exposed part of the eyeball. In *Mustelus* the membrane can only cover a comparatively small part of the eyeball, but by way of compensation the upper eyelid can be drawn down to meet it. *Triacis* resembles *Mustelus* in the extent of development of the nictitating membrane; while *Galeus*, although possessing distinct upper and lower eyelids meeting in a sharp angle posteriorly as in *Mustelus*, has a membrane almost as broad as that of *Carcharias*. *Zygæna*, on the other hand, has a circular eyelid like *Carcharias*, but the nictitating membrane is less fully developed than in this genus.

MUSTELUS.—The largest and most important muscle of the series, the only one, in fact, mentioned by Joh. Müller, is the *levator palpebræ nictitantis*¹ (fig. 1, *l.p.n.*). It is connected with the posterior part of the nictitating membrane by a broad flat tendon, and runs backward and slightly upward, and is attached to the lateral surface of the auditory region of the cranium, above the level of the post-orbital groove, in which runs the vein carrying the blood from the orbital sinus to the anterior cardinal sinus. The extreme posterior end of the muscle is overlapped by the great superficial dorsal constrictor innervated by the seventh nerve (*csd ii.* of Vetter, 9), and lies just above the foramen by which the glossopharyngeal nerve issues from the skull. The muscle passes dorsally to the spiracle, externally to the descending post-orbital mucus-tube, and externally also to the *levator maxillæ superioris*, with the upper end of which its

¹ So named by Tiesing (8, p. 92) and Ruge (7, p. 231). It is the *Nickhautmuskel* of Müller (6, p. 121), and the *M. nictitans* of Hubrecht (2, p. 100).

posterior end is more or less continuous. The upper edge of the muscle is overhung by the post-orbital process of cartilage. The nerve which supplies it is frequently double, and arises from the maxillo-mandibular division of the trigeminal, almost immediately on the appearance of the latter in the orbit. The nerve passes backward, and leaves the orbit just ventral to the orbital opening of the post-orbital groove. Continuing backward, between the cranial cartilage and the *levator maxillæ superioris*,

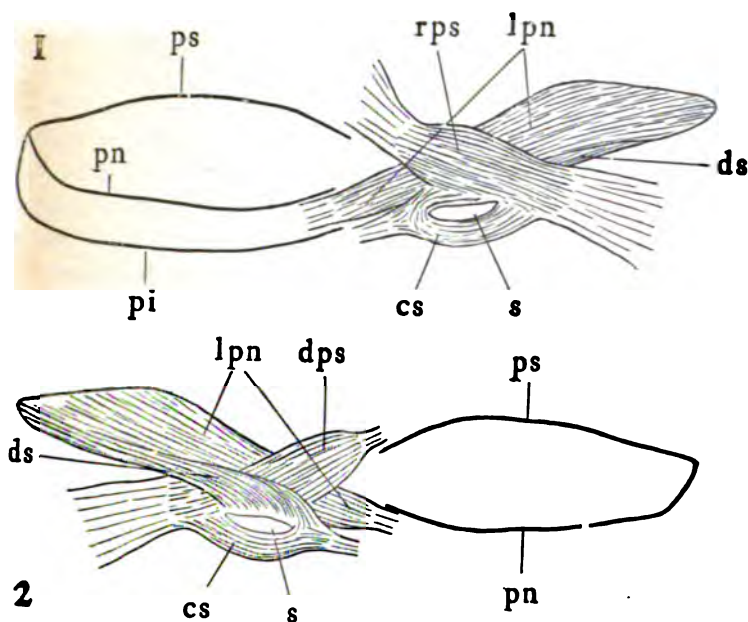


FIG. 1.—*Mustelus vulgaris*. Muscles of the eyelids; external view.

FIG. 2.—The same, seen from the inner side. *ps*, upper eyelid; *pi*, lower eyelid; *pn*, nictitating membrane; *lpn*, levator palpebræ nictitantis; *dps*, depressor palpebræ superioris; *ds*, dilator spiraculi; *cs*, constrictor spiraculi; *rps*, retractor palpebræ superioris; *s*, spiracle.

sometimes traversing the innermost part of this muscle, the nerve finally enters the inner or mesial surface of the *levator palpebræ superioris* at about one-fifth of its length from the posterior end.

The fibres of the lowermost edge of the muscle do not continue forward to the nictitating membrane, but separate off and spread out into the firm fibrous tissue of the dorsal and anterior walls of

the spiracle. Although the postero-superior part of this muscular tract cannot be distinguished from that of the *levator palpebræ nictitantis* (see fig. 2, *ds*), and in spite of the community of nerve supply, it is convenient to consider this as a distinct muscle—the *dilator spiraculi*. By its contraction, the dorsal wall of the spiracle is raised, and the aperture consequently enlarged. Some of the fibres run back again in the form of a thin sheet to the internal surface of the *levator palpebræ nictitantis*. (These recurrent fibres are not shown in figure 2.) This *dilator spiraculi* is the *csd 1 γ* which Tiesing (8, p. 93) claims to have discovered, although it is clearly referred to by Hubrecht in the following words (2, p. 100):—“Bei *Mustelus* und *Galeus* ist ausserdem noch ein schwacher Muskel zu bemerken, welcher von der lateralen Fläche des Cranium, unter dem Postorbitalfortsatze entspringt und längs der oberen Wand des Spritzlochcanals verlaufend, seine Fasern in diejenigen des Spritzlochschiessmuskels ausstrahlen lässt.”

The upper eyelid is furnished with a special muscle (fig. 2, *dps*) which lies on the inner side of the *levator palpebræ nictitantis*, and arises from the dorsal wall of the spiracle, chiefly to the external side of the *dilator spiraculi*, although a few of the fibres of the latter, namely, those returning to the *levator palpebræ nictitantis*, are wedged in between it and the *levator palpebræ nictitantis*. The muscle thins off rather suddenly in front, and is attached to the hinder extremity of the upper eyelid by a short tendon. Seeing that the muscle is oblique, and by its contraction draws down the upper eyelid, it is better termed the *depressor palpebræ superioris* than the *retractor palpebræ superioris*, the name given to it by Tiesing (8, p. 93, *csd 1 β*). Hubrecht has not specially mentioned it in *Mustelus*, and so Tiesing is more or less justified in his claim to its discovery, but that the former morphologist knew of its existence is evident from his incidental allusion to the *deep muscle* to the upper eyelid having united with the superficial one to form in *Carcharias* the noose through which the *M. nictitans* passes (2, p. 100). This muscle, by its contraction, assists the *dilator spiraculi* in dilating the spiracular aperture; the latter muscle draws the roof of the spiracle backward and upward, the *depressor palpebræ superioris* draws it forward and upward, so

that in a simultaneous contraction of the two muscles the resultant movement is in an upward direction. The narrowing of the muscle at its anterior end, however, shows that this is the relatively free end, and the other, attached to the spiracular wall, the relatively fixed end, and for this reason the muscle is to be regarded as a depressor of the upper eyelid rather than as a dilator of the spiracle.

Closely associated with the foregoing muscles is a superficial *constrictor spiraculi* surrounding the external aperture of the spiracle. This is fundamentally a sphincter muscle (fig. 1, *cs*), but the dorsal part is much more strongly developed than the ventral, and spreads out into an aponeurosis over the external surface of the *constrictor superficialis dorsalis* ii. posteriorly, while anteriorly its belly leaves the sphincter proper, and, passing slightly upwards, terminates in an aponeurosis closely adherent to the integument of the upper eyelid. Seeing that the action of this dorsal part (fig. 1, *rps*) is distinct from that of the circularly arranged fibres, it is convenient to retain for it the title of *retractor palpebræ superioris* given by Ruge (7, fig. 5). It is not the *retractor palpebræ superioris* of Tiesing (8, p. 93), which lies deeper; but it is probably referred to in the following sentence by Hubrecht:—"Von dem *Constrictor spiraculi* sondert sich ein bei der erwähnten Gattungen ziemlich starkes Faserbündel ab, welches von dem gleich zu erwähnenden *M. nictitans* nach vorn und oben verläuft und sich im oberen Augenlide am hinteren Augenwinkel verliert." A feeble aponeurosis also extends from the anterior part of the sphincter to the lower eyelid. These muscles are very closely bound to the skin by a tough white fibrous tissue, which renders their dissection a matter of some difficulty. Only the posterior and dorsal parts of the constrictor appear to have been recognised by Hubrecht (2, p. 99), but he is correct in his description of the part which runs to the upper eyelid (2, p. 100). Tiesing makes no special mention of these superficial muscles, but it would seem from his figure (8, pl. 6, fig. 8) that a part at least of the *retractor palpebræ superioris* is included in his *csd 1 γ*.

In TRIACIS the muscles of the eyelids and spiracle are exactly as in *Mustelus*.

In GALEUS, as already mentioned, the nictitating membrane is

proportionately larger than in *Mustelus*, and can cover a relatively greater portion of the eyeball. But a more important feature than this, indicating the higher degree of specialisation of the nictitating apparatus of *Galeus*, is the absence of placoid spines on the inner surface of the lower eyelid. In this respect the genus approaches *Carcharias*, and departs from *Mustelus*. The muscles are essentially the same as in *Mustelus*, although the small size of the spiracle has the effect of making the spiracular muscles look disproportionately large. The *levator palpebræ nictitantis* is relatively longer, and slopes less backward and more inward than in *Mustelus*, while the *dilator spiraculi* is also more upright, and the part of it which runs back to rejoin the *levator palpebræ superioris* is better defined than in *Mustelus*. The hind end of the *depressor palpebræ superioris* thus appears to be embraced by the bifurcated *dilator spiraculi*. Allis's remarks (1, p. 571) on the spiracular muscles of *Galeus* are not accompanied by illustrations, and are thus somewhat difficult to follow, especially as he calls the nictitating membrane the "lower eyelid," and speaks of the nictitating muscle as the "larger spiracular muscle." The muscle to the upper eyelid, which he describes as "allowing the larger spiracular muscle to pass through," is evidently the *retractor palpebræ superioris* and the *depressor palpebræ superioris*, together regarded as a single muscle. I have not succeeded in finding any connection between the *levator palpebræ nictitantis* and the upper jaw such as that mentioned by Allis.

In *CARCHARIAS* there is a circular eyelid, in which the upper and lower constituents are not differentiated, and which appears to be incapable of change in shape. A very extensive nictitating membrane serves to cover the conjunctiva when necessary. Its muscle, *levator palpebræ nictitantis* (figs. 3 and 4, *l p n*), is long, about three times the diameter of the circular eyelid, and after passing backward for a short distance, runs the rest of its course inward and upward, and very slightly backward. The muscle thus lies almost in a plane transverse to the axis of the head, whereas in *Mustelus* the *levator* is nearly parallel to the axis. It is attached to the auditory region of the skull, behind the base of the rod-like post-orbital cartilage, and in close relation with the upper end of the *levator maxillæ superioris*. The nerve

which is a branch of the mandibular nerve, enters the inner surface of the muscle at one-fifth of its length from the upper or inner end. There is no spiracle, but the position which that would occupy is clearly marked by the lower end of the readily distinguishable *dilator spiraculi* (figs. 3 and 4, *ds*). In the absence of the spiracle, the end of the muscle is attached to the skin instead of the roof of the meatus.

The muscular noose of Müller (6, p. 122), through which the

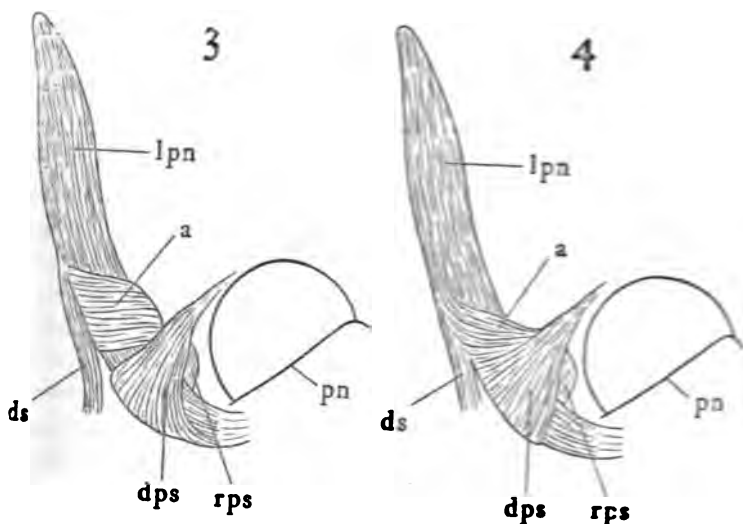


FIG. 3.—*Carcharias acutus*.

FIG. 4.—*Carcharias laticaudus*. Muscles of the eyelids dissected from the inner side. *a*, accessory muscle (see text); other letters as in Fig. 1.

nictitating muscle passes, has both its extremities directed forwards and upwards, and both are attached to the integument of the eyelid. The limb of the muscle lying to the inner side of the *levator palpebræ nictitantis* (figs. 3 and 4, *dps*) thins away considerably, and terminates in a long tendon attached to the dorso-posterior border of the eyelid. The external part of the muscle is attached, without diminution in width, to the skin at the posterior border of the circular eyelid (figs. 3 and 4, *rps*). Hubrecht (2, p. 100) has considered this muscular noose as due to the union, behind the *levator palpebræ nictitantis*, of those muscles of *Mustelus* here called the *retractor palpebræ superioris*

and the *depressor palpebræ superioris*. Both of these muscles are normally related to the dorsal wall of the spiracle, and it is not unreasonable to suppose that on the disappearance of the spiracle their broad posterior ends should have joined into one continuous belly. No trace is left of the *constrictor spiraculi*.

In *Carcharias laticaudus* some of the fibres of the *dilator spiraculi* bend forward (fig. 4, *a*) and join on with those of the inner part of the muscular loop, but in *Carcharias acutus* the muscular tissue which occupies the same position (fig. 3, *a*) is differently related to its surroundings at both ends. Posteriorly it arises from the connective tissue between the *dilator spiraculi* and the *levator palpebræ nictitantis*, and its fibres cannot be traced into either of these muscles. Its anterior end, instead of running forward to join the *depressor palpebræ superioris*, bends outwards in front of the *levator palpebræ nictitantis*, and becomes attached to the skin. A further difference between these two species lies in the fact that some of the lower fibres of the *depressor palpebræ superioris* run downward and forward to join the *levator palpebræ nictitantis* in *Carcharias acutus*, while in *Carcharias laticaudus* the two muscles are distinct.

In *ZYGÆNA* the nictitating apparatus is somewhat exceptional, as might have been expected in a head of such abnormal proportions. The *levator palpebræ nictitantis* in *Zygæna tudes* arises from the posterior surface of the thin rod of cartilage usually known as the post-orbital process. Its origin is tendinous, and the tendon is long, and can be traced for some distance towards the cranium, but not as far as the base of the post-orbital process. Hubrecht (2, p. 100) speaks of the nictitating muscle of *Zygæna* as coming off the *base* of the post-orbital process, and Müller (6, pl. v. fig. 3) has figured it arising in the same position. Neither Müller nor Hubrecht mention the species of *Zygæna* examined, but the proportions of the head in Müller's figure show that his species was *Z. malleus*, and this being the commoner species, Hubrecht's was probably the same. The discrepancy may, therefore, prove to be due to specific differences.

As the *levator palpebræ nictitantis* passes across the ventral plate of cartilage supporting the side of the head, it increases considerably in size, but diminishes again on nearing the eye (fig. 5, *l p n*). It is inserted, without tendinous extremity, into

the posterior end of the nictitating membrane. The *dilatator spiraculi* (fig. 5, *ds*) is a thin muscular strand arising from the dorsal side of the *levator palpebræ nictitantis*, and therefore largely hidden by the latter in a ventral view. It follows the *levator palpebræ nictitantis* for the greater part of its course, and is ultimately attached to the skin below the extreme lateral margin of the head, and a short distance behind the eye.

There still remains to be described a confused mass of muscle (fig. 5, *b*) situated between the cutaneous insertion of the *dilatator*

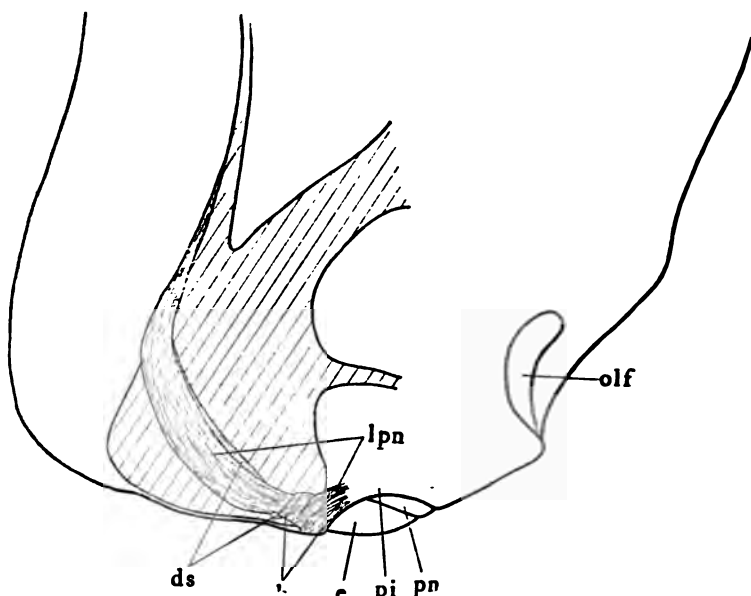


FIG. 5.—*Zygæna tudes*. Dissection of left side of head; ventral view. *e*, eye-ball; *b*, muscular noose; *olf*, nasal aperture; other letters as in Fig. 1.

spiraculi and the eye, and more or less related to the anterior extremity of the *levator palpebræ nictitantis*. This represents, in a modified form, the muscular loop surrounding the anterior end of the *levator palpebræ nictitantis* in *Carcharias*; and it is probably this to which Hubrecht refers (2, p. 100) as the “verstärkende Fasern von der unteren Fläche des an seinem Ende plattenförmig verbreiterten Antorbitalfortsatzes,” for he regards the antorbital process as extending backward behind the eye. But,

as a matter of fact, the fibres are not attached to the cartilage. When dissected from the ventral surface, the muscular tract appears divisible into three strands, the external parts of these strands, *i.e.*, those farthest from the median plane of the body, being contiguous. The posterior of the three is a complete loop, the two ends of which pass upward and forward, and are attached to the postero-dorsal border of the circular eyelid. This is in reality the largest of the three strands, but in a ventral view the greater part of it is concealed by the other two. It loops round the *levator palpebræ nictitantis*, and represents the muscular noose already described in *Carcharias*. The middle and anterior strands are confined to the ventral side of the *levator palpebræ nictitantis*, and are both attached peripherally to the tough subcutaneous tissue behind the eye. The middle one is narrow, and runs forward to join the anterior end of the *levator palpebræ nictitantis*; the anterior is parallel to it, but is attached to the postero-ventral edge of the lower eyelid. In *Carcharias acutus* it has already been shown that some of the lower fibres of the muscular noose run on to the *levator palpebræ nictitantis*, and so the middle strand here is not without its counterpart in the genus *Carcharias*; but the anterior division inserted into what might be called the lower eyelid is not represented in any of the other *Carchariidæ* examined.

SCYLLIUM.—Having thus reviewed the musculature of the nictitating apparatus of the *Carchariidæ*, it now remains to be seen whether the muscles of the eyelids of *Scyllium* can be compared in detail with those already described, or whether they are modelled upon a distinct type. The muscle to the nictitating membrane (fig. 6, *lpn*) is powerful, and its anterior flattened tendon extends for some distance forward into the membrane. Its posterior extremity is related to its surroundings as in the *Carchariidæ*. It is in close connection with the upper extremity of the *levator maxillæ superioris*, is attached to the external surface of the auditory capsule, above the level of the post-orbital groove, and is overhung by the post-orbital process of cartilage.

Were it not for the relations of the nerve supplying it there would not be the slightest hesitation in regarding this muscle as the perfect homologue of that of the *Carchariid* sharks. The

nerve, it is true, is a branch of the trigeminal, and separates from the postero-superior surface of the maxillo-mandibular division just as the latter emerges through the cranial wall into the orbit. It is also inserted into the internal surface of the muscle close to the posterior end. But in its course it passes to the *external* side of the *levator maxillæ superioris*. Whether this fact is of any great importance it is difficult to decide. In

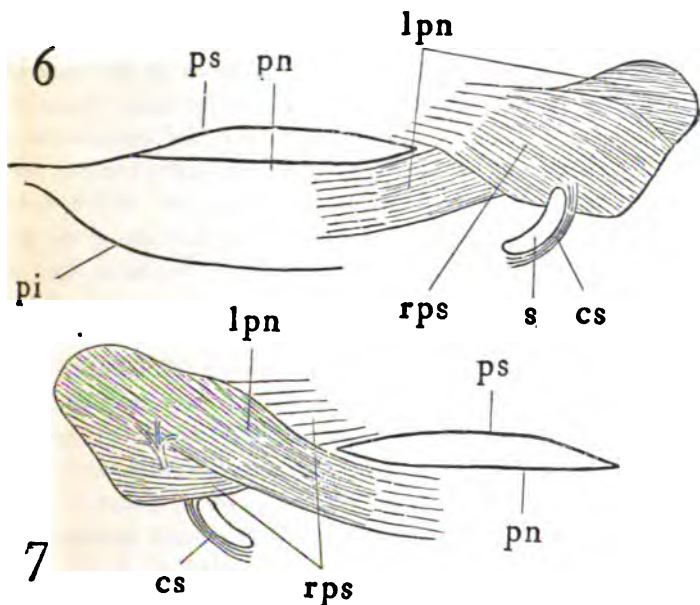


FIG. 6.—*Scyllium canicula*. Muscles of the eyelids; external view.

FIG. 7.—The same, seen from the inner side. Letters as in Fig. 1.

both *Scyllium* and the *Carchariidæ* the nictitating muscle evidently belongs to the same system of primitive dorsal constrictors as the *levator maxillæ superioris*, and its nerve has a common origin with that supplying the *levator maxillæ superioris*, but the passage of the nerve of the *levator palpebræ nictitantis* on the opposite sides of the *levator maxillæ superioris* in the two types points rather to an independent evolution of the muscle. This view is further supported by the relations of the large muscle attached by its tendinous anterior extremity to the upper eyelid of *Scyllium* (fig. 6, *rps*). This is evidently not the *depressor palpebræ superioris* of *Mustelus* and *Galeus*, for it lies

external to the *levator palpebræ nictitantis*, and it arises, in common with the posterior end of the *levator palpebræ nictitantis* (see fig. 7), from the auditory cartilage, and not from the roof of the spiracular meatus.

The name *retractor palpebræ superioris* is here given to the muscle only provisionally, for it does not appear to be the exact counterpart of the *retractor palpebræ superioris* of *Mustelus*. This latter, although similarly related to the upper eyelid, belongs primarily to the system of the spiracular muscles, and is, in fact, the greatly enlarged upper portion of the spiracular sphincter. It also retains its superficial position posteriorly, and is continued as an aponeurosis over the exterior of the dorsal constrictor supplied by the seventh cranial nerve, whereas the *retractor palpebræ superioris* of *Scyllium* dips beneath this muscle, and is attached to the cartilage of the skull. That the *retractor palpebræ superioris* of *Scyllium* does not belong to the spiracular system is further demonstrated by its being crossed almost at right angles by the more superficially placed upper end of the *constrictor spiraculi*. This latter muscle (fig. 6, *cs*) is very feebly developed, and can only be traced around the postero-inferior border of the spiracular aperture. The apparent notching of the *retractor palpebræ superioris* seen in figure 6, by the upper border of the spiracle, is due to the fact that the external part of the spiracular meatus spreads somewhat in a dorsal direction over the outer surface of the muscle, and is in this part supported by the *constrictor spiraculi*. The same effect is not obtained when dissecting from the inner surface, for the size of the meatus in the plane of the *retractor palpebræ superioris* is less. Since the *retractor palpebræ superioris* and the *levator palpebræ nictitantis* of *Scyllium* are supplied by the same nerve (see fig. 7), and since, when seen from the inner surface, the posterior parts of the two muscles are continuous, no doubt can be entertained as to their origin from a common primitive tract.

The foregoing observations admit of the following conclusions. The structure of the eyelid musculature in *Mustelus*, *Triacis*, *Galeus*, *Carcharias*, and *Zygæna* points to a natural affinity between the members of the Carchariidæ, and justifies the

recognition of the nictitating membrane as a character diagnostic of a natural family. The mode of origin of the nictitating membrane in these sharks is probably illustrated by the condition already reached by the palpebral folds of *Scyllium*, although the want of conformity of the eyelid muscles of *Scyllium* with those of the above genera suggests an independent evolution of the third eyelid in it and the Carchariidæ. There is thus no reason to believe that *Scyllium* is at all closely related to the Carchariidæ.

With regard to the mode of origin of the nictitating membrane, although Müller (6, p. 121) has described it as a duplicature of the skin developed from the inner surface of the lower eyelid, it appears more reasonable to suppose that the primitive lower eyelid has become converted into the nictitating membrane, and that a new duplicature of skin below this has developed into the existing lower eyelid. Without relying upon the transitional state of these parts in the genus *Scyllium*, there is one very important item of evidence within the family Carchariidæ to support this view, and that is the presence of dermal denticles on the inner surface of the lower eyelid in *Mustelus*. According to Müller's view, the inner surface of the lower eyelid was originally in contact with the eyeball, in which case it is highly improbable that it was covered with denticles. The shagreen, therefore, occurring in this position in *Mustelus* is, according to Müller's view, newly developed, and the condition must be regarded as more specialised than that which occurs in *Carcharias*, although Müller himself admitted that the nictitating apparatus of *Carcharias* is the more highly developed. But on the assumption that the lower eyelid is a new duplicature of skin, its inner surface will at first be covered with denticles, as in *Mustelus*, but in order to reduce the friction between it and the nictitating membrane its internal armature will tend to become reduced with increased specialisation, and ultimately lost altogether, as in *Galeus* and *Carcharias*.

In both *Scyllium* and the Carchariidæ the *levator palpebræ nictitantis* is a muscle differentiated from the same primitive tract as the *levator maxillæ superioris*, and the *retractor palpebræ superioris* of *Scyllium* and the *dilator spiraculi* of the Carchariidæ belong undoubtedly to the same category,—a conclusion which

indorses the views already set forth by Hubrecht (2, p. 106). Tiesing (8, p. 92), and Allis (1, p. 571). The *depressor palpebræ superioris* (*retractor palpebræ superioris* of Tiesing and Allis) may possibly be derived from the same source, as maintained by these authors; in which case the *levator palpebræ nictitantis*, the *dilator spiraculi*, and the *depressor palpebræ superioris* of the Carchariidæ would together represent that undifferentiated pre-spiracular muscle of *Heptanchus* which Vetter has described as the *constrictor superficialis dorsalis i.* (9, p. 408). The mode of origin of the *retractor palpebræ superioris* and the *constrictor spiraculi* cannot be considered as settled; they appear to belong to a purely dermal system of muscles.

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THE PENETRATION OF THE MUSCULAR FIBRES OF
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EXISTENCE IN THAT ORGAN OF VERY LARGE
CAPILLARIES. By ARTHUR V. MEIGS, M.D., *Physician
to the Pennsylvania Hospital.* (PLATE IV.)

THE capillaries of the human heart differ in two ways from those of other parts of the body: they penetrate the muscular fibres, and some of them are larger than those found elsewhere, and of different arrangement. The subject was discussed by me some years ago,¹ but it is possible now to describe more particularly the anatomical peculiarities which have been mentioned, as I have lately obtained additional proof of their existence from the study of preparations of hearts in which the blood-vessels had been injected. The accompanying illustrations are drawings which were made with the camera lucida. They are from sections of two human hearts. The first is that from which the illustrations of my original paper were made, and is the heart of a negro woman 40 years old, who died of burns. Some pieces of the organ were preserved in Fleming's solution, and others in 70 per cent. alcohol, and they were stained in bulk with borax-carmin and embedded in paraffin. The second heart is that of a man 30 years old, who died of lead encephalopathy. When the post-mortem examination was made, the heart being still quite fresh, there was injected through each of the two coronary arteries as much as the blood-vessels would easily receive of a solution of 3 grammes of Berlin blue (Grübler's) in 600 cubic centimetres of water. Pieces of the organ of suitable size were at once placed in preservative fluid, some in 70 per cent. alcohol, and others in formaldehyde solution. The tissue was afterwards stained in bulk with borax-carmin and embedded in paraffin.

The penetration of the muscular fibres by the capillaries is made perfectly clear by the illustrations; it is shown as well by

¹ *Transactions of the College of Physicians of Philadelphia*, April 1, 1891; the *American Journal of the Medical Sciences*, June 1891; and the *Origin of Disease*, etc.; by Arthur V. Meigs. Philadelphia: J. B. Lippincott Co., 1897,—p. 63.

the injected as by the uninjected heart. The two methods of demonstration supplement one another, because, in injected tissue which has been stained, the blood-vessels and their situation are made very obvious by the contrast of colour, but the details of the structure of the walls are obscured by the injection material, while, on the other hand, in the uninjected tissue, the structure of the blood-vessels can be seen with the utmost distinctness. In figs. 1 to 4 the capillaries are easily recognised. Their situations in relation to the muscular fibres are very varied. Some are in the intermuscular spaces, others slightly indent the sides of the fibres; still others are within the fibres close to their peripheries, and sometimes the capillaries are in the very centres of the fibres. This penetration of the muscular fibres of the human heart in the adult is a most striking and curious phenomenon, and it does not exist at an early embryological stage. The condition is therefore one of later development, but it is not yet known at how early an age it does exist. It would be interesting and useful to examine young human hearts to ascertain when capillaries are first found within the muscular fibres.

This aspect of the subject was considered by the late Dr John A. Ryder. In discussing my original communication he said: "Many of the structures that we see in the adult organ are really developed during what embryologists speak of as the post-embryonic period. When we reflect upon the way in which muscle universally develops, no matter whether it be in the salamander, the fish, reptile, bird, or mammal, we can see how, in the later stages of the development of the heart, such a thing as enveloping or inclusion of capillaries might occur. It is well known to everyone who has made a cross-section of a developing muscle, that the fibrillæ appear as delicate threads imbedded in the protoplasm forming the body of the muscle cell. That is the type found in the highest form of muscular development. There are forms of muscular development in which the fibrillæ are developed in a continuous roll, and, as a result, the muscular fibre resembles a flat plate made up of parallel filaments. However, as we pass up in the animal scale, and particularly in mammals and birds, the muscular fibres become irregular in shape, and excessively numerous and closely packed

together, with very little protoplasm between. When we remember that the multiplication of the fibrillæ seems to result from splitting up or multiplication of the fibres already present, we can understand that, as the muscular fibres grow in thickness, any capillaries that might lie beside them might readily be engulfed and covered in by the multiplying fibres."

In a paper on the Histology and Histogenesis of the Heart-muscle Cell by John Bruce McCallum (*Anatomischer Anzeiger Centralblatt für diegesammte wissenschaftliche Anatomie*, xiii. Band, No. 23, 1897), it is shown that during early embryological stages the muscle-cells are composed of undifferentiated sarcoplasm, even after the heart has begun to beat, in the case of the chick. The characteristic cross striae appear at a later period, and show themselves first in the more superficial layers of the heart. Therefore, it is evident that during the early stages the capillaries are not within the muscle-cells. McCallum quotes Schiefferdecker as saying that "after the tenth year yellowish-brown pigment is present at the poles of the nucleus in human heart muscle. As age advances the pigment increases in quantity, and the granules become larger in size and of a deeper colour."

It has been shown that the capillaries do penetrate the muscle-fibres of the adult human heart, and it is certain that they are not within the fibres during the early stages of development; it is probable, therefore, that the capillaries get within the fibres by a process of inclusion, as was suggested by Ryder. The pigment which is found at the poles of the nuclei in the adult heart is absent during early life, and there is much reason to believe that it is somehow connected with the penetration of the muscular fibres by the capillaries. In future it must be remembered that the nuclei in the muscular fibres are not all muscle nuclei, but that the capillaries, in penetrating the fibres, necessarily carry their own nuclei with them (fig. 1, c, and fig. 4, d).

Very large capillaries are found in the human heart, and such vessels are shown by figs. 5 and 6. It is not common to find minute veins in company with the arterioles in the deepest portions of the muscular substance of the heart, although it is well known that upon the surface and in the connective tissue

interstices, arteries are found with their venæ comites, just as they are in other organs and tissues. The arrangement of the vessels upon the surface and in the interstices is in marked contrast with that found in the muscular substance proper. Here, when an arteriole is accompanied by an efferent vessel, this vessel is single coated and composed of endothelium, being exactly like the smallest capillaries, except in size. These peculiar large capillaries are found not only in company with arterioles, and, therefore, when carrying on the function usually performed by veins, but also alone. When they are alone, it is impossible to be certain whether their function was afferent or efferent. It may well be that arterioles are less numerous in the heart than in other tissues, and that their place is taken by the large capillaries. These capillaries are so numerous and of such size that it seems likely they perform the function of reservoirs. The presence of the large capillaries and the penetration of the muscular fibres by the capillaries indicate a provision for the blood supply of the heart even more bountiful than that of the other organs.

DESCRIPTION OF PLATE IV.

Scales are included with the plate showing the amplification.

Fig. 1. $\times 420$. From a man 30 years old, who died of lead encephalopathy. A section of papillary muscle of the heart cut across the fibres: *bb* are injected capillaries, the one partially and the other entirely within the muscular fibres; *c*, a capillary which remains uninjected, its nucleus is included.

Fig. 2. $\times 420$. From the same tissue as fig. 1. *v*, a vein stained by the injection material; *bb*, capillaries whose precise situation cannot be defined. They cannot be said to be in inter-muscular spaces, nor to be entirely within fibres. The effect is as if the fibres were coalescing.

Fig. 3. $\times 420$. From the same tissue as fig. 1. *f*, a capillary in a fibre; *g*, a capillary in the centre of a very small fibre. This is perhaps the most convincing instance of the penetration of a muscular fibre by a capillary.

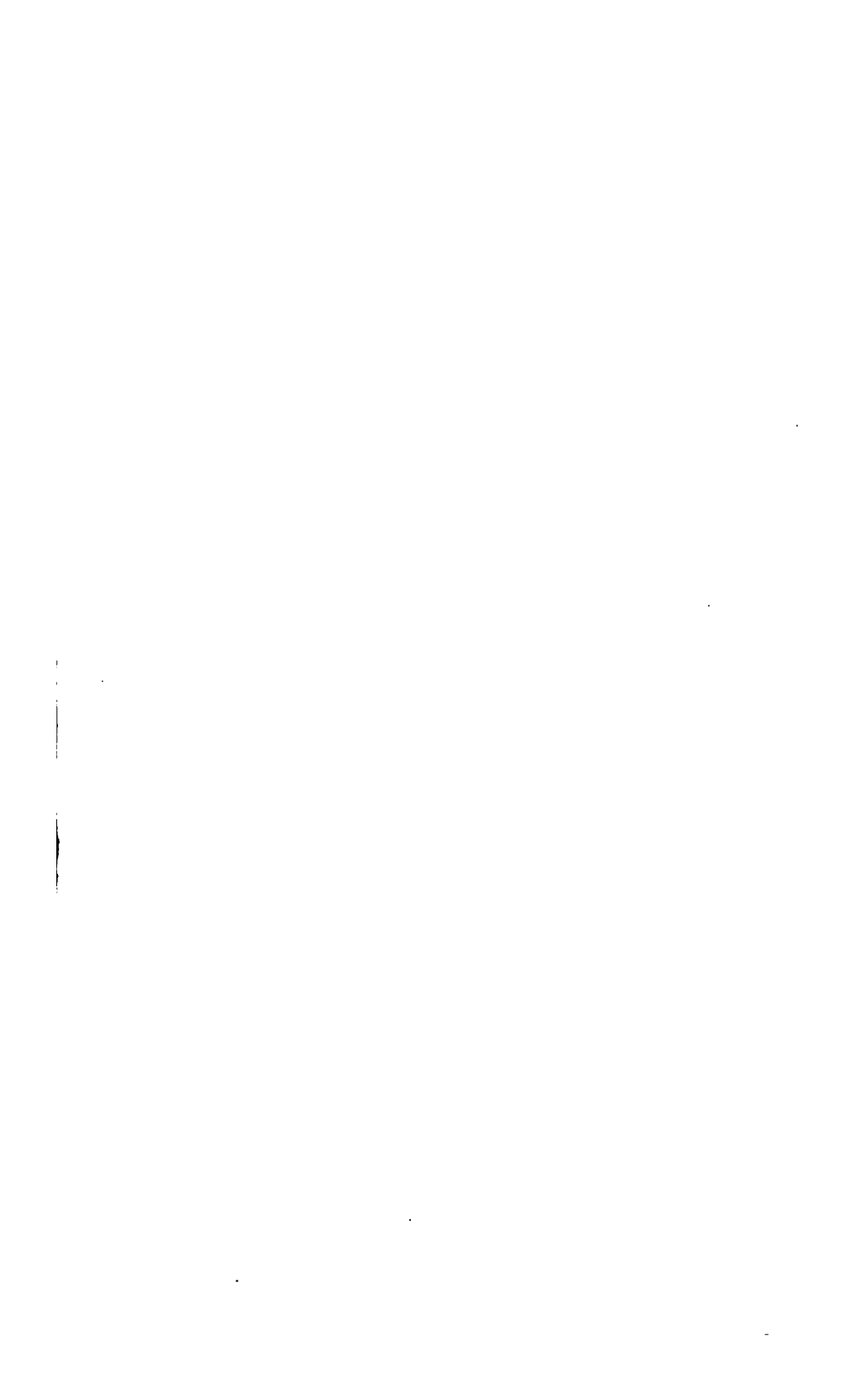


Fig. 1.

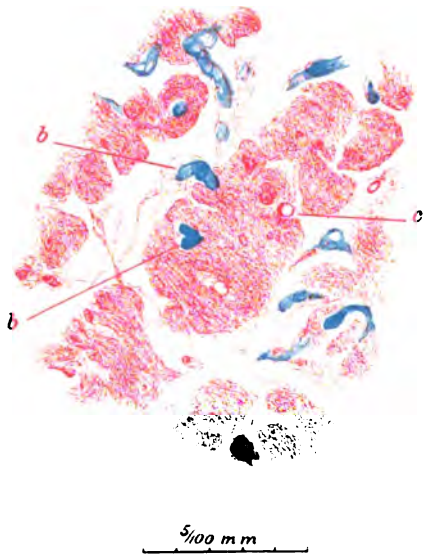


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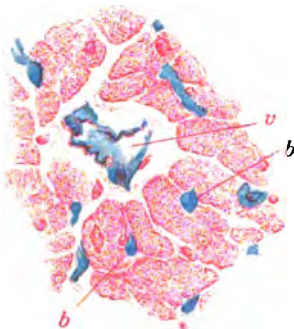


Fig. 3.

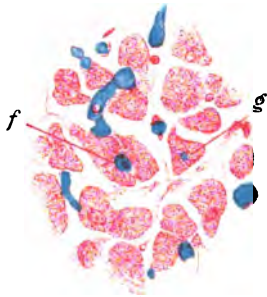


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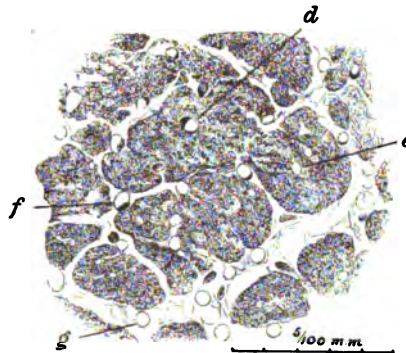


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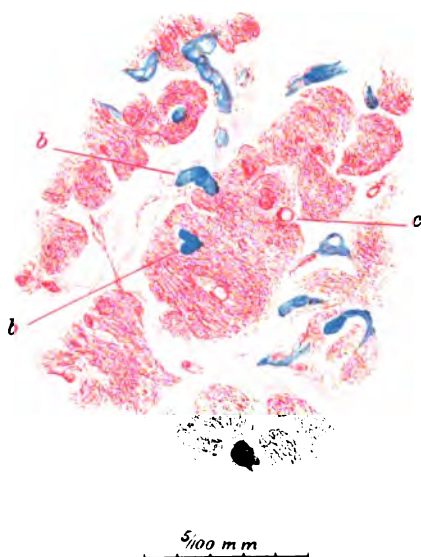


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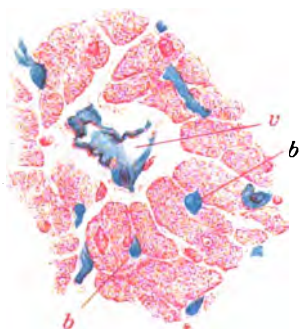


Fig. 3.

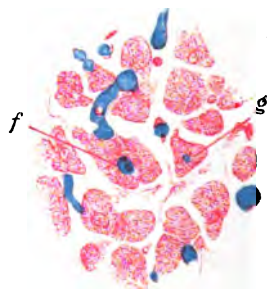


Fig. 4.

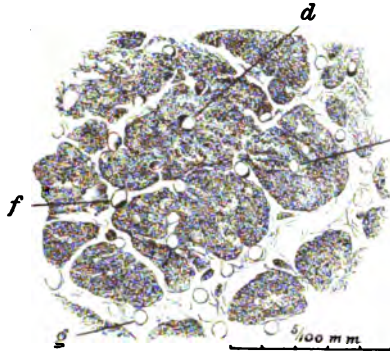
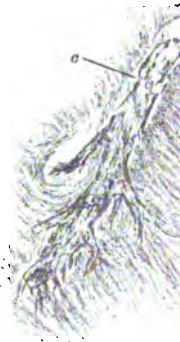
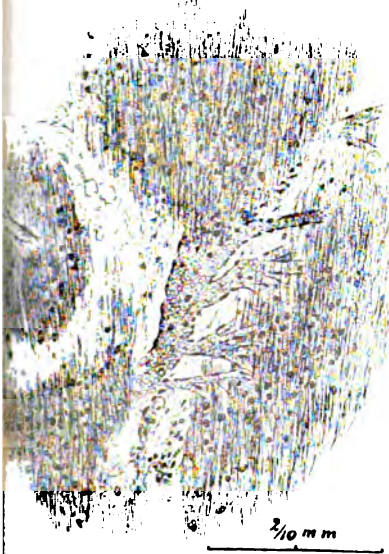


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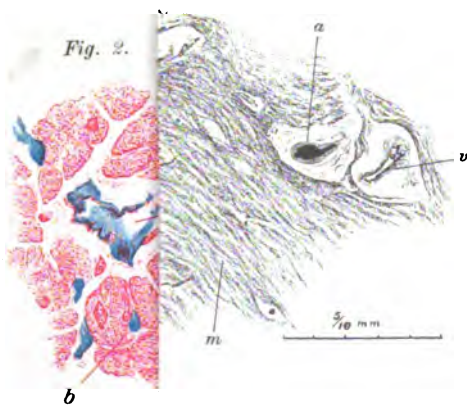


Fig. 4. $\times 420$. A section of heart cut transversely to the muscular fibres, from a negro woman 40 years old, who died of burns. The muscular fibres are of irregular shape. *d*, a capillary within a muscular fibre, its nucleus upon one side producing a resemblance to a seal ring; *e*, a capillary within a muscular fibre; *f*, a capillary in an intermuscular space: its nucleus being included, it resembles a seal-ring; *g*, a capillary in an intermuscular space: its endothelial wall appears as a simple circle.

Fig. 5. $\times 115$. From the same tissue as fig. 4. A large capillary, receiving many branches and surrounded by muscular tissue. The capillary and its branches are almost filled with blood corpuscles. The capillary walls are distinctly visible, containing many flattened endothelial nuclei.

Fig. 6. $\times 42$. From the same tissue as fig. 1. Not printed in two colours, because the essentials show equally well in black. *m*, muscular tissue; *a*, an arteriole. The solid black within its calibre is injection material. *v*, the accompanying vein to the arteriole *a*; it also contained a little of the injection material: these two vessels are in a connective-tissue interspace; *c*, a large capillary: it contains a good deal of the blue injection material, which is represented by the heavily-shaded portions. These three vessels—arteriole, vein, and capillary—give a good idea of the character of such vessels in the heart. The great size of the capillary is the most striking feature.

[In vol. iv. p. 113 of this *Journal* (Nov. 1869), Dr T. A. CARTER described and figured, in an injection of the capillaries of the diaphragm, of the muscular substance of the tongue and of the wall of the abdomen, the penetration of the injection within the sarcolemma of some of the muscular fibres owing to the passage of delicate offshoots of the capillaries which pierced the sarcolemma and then ran parallel to the fibrillæ.—EDITORS.]

OBSERVATIONS ON THE SHAPE OF THE SOLID
ABDOMINAL ORGANS. By DAVID HEPBURN, M.D.,
F.R.S.Ed., *Lecturer on Regional Anatomy, University of
Edinburgh.*

THE application of formalin to the preservation and hardening of animal tissues has given a new stimulus to the examination of internal organs, and has led to results much more readily obtainable, besides being much more permanent, than those which were derived from the use of freezing mixtures of ice and salt in the making of sections followed by reconstruction. For the purpose of hardening organs *in situ*, formalin serves admirably in solutions of from 5 per cent. to 10 per cent. in strength. If the desire be to study the relations of internal organs to the surface of the body, the position in which the 'subject' lies during the hardening process will undoubtedly influence the results obtained whatever hardening process may be adopted, but for the mere determination of the natural shape of an organ the amount of variation due to the attitude of the 'subject' is not sufficiently large to vitiate the object in view.

The investigations of His, Cunningham, Symington, Birmingham, and Dixon have revolutionised our ideas regarding the shapes of internal organs, besides throwing floods of light upon the manner in which these organs are 'packed' together. Not the least important class of information is that which pertains to the solid abdominal organs, for it has been proved that they receive and retain upon their surfaces the 'impressions' produced by contact with and pressure from the surrounding solid organs in their immediate neighbourhood.

However, we must not fall into the error of supposing that the solid abdominal organs present at all times during life the facettèd appearances which characterise them after death, for as the hollow viscera are constantly changing their dimensions, so the solid viscera must similarly present larger or smaller surfaces of contact with the hollow viscera and with each other. But in so far as facetting expresses the mutual relationships existing between viscera, it is of extreme value in providing an

accurate record of these relationships, even although to some extent it may be exaggerated by post-mortem flaccidity. It is not necessary for me to discuss the question of solid viscera impressing hollow viscera, since at present I have no evidence to offer either for or against this proposition.

No doubt the normal shapes of solid organs are subject to variation within certain limits, but still in their main features they conform to definite standards of outline and general configuration. On this account I have thought it advisable to describe the appearances of a series of adult solid abdominal organs which seem to me to present features of interest and importance as bearing upon the data which are given in anatomical text-books concerning the shapes of these organs.

The organs in question were taken from a well-nourished adult male 'subject' which had been preserved in a 5 per cent. watery solution of formalin. During the process of injection the 'subject' lay upon its back. Afterwards it lay upon its face for the removal and study of the brain and spinal cord. In each of these positions not more than two days were spent, and at the end of this time the 'subject' was again placed upon its back in order to undergo the usual process of dissection. Reference is made to these details to show that the markings on the solid organs are not due to the influence of prolonged rest in one position.

The Kidneys.—The most recent views concerning the shape of the kidneys are embodied in the last edition of *Quain's Anatomy* (vol. iii. pt. 4, p. 191), where it is stated that the kidney is 'bean-shaped,' and possesses two surfaces, two borders, and two extremities. From an examination of the specimens under consideration, it appears to me that this statement is capable of extensive modification, and that it would be in accordance with these appearances to describe the general configuration of the organ as prismatic, presenting three surfaces, three borders, and two extremities, of which the lower was pyramidal and the upper more or less rounded and blunt.

The entire kidney adapted itself to the re-entrant angle formed by the psoas and quadratus lumborum muscles, and its surfaces were directed in accordance with this position. Thus, the mesial or internal surface rested upon the outer aspect of the psoas

muscle, while the dorsal or posterior surface was associated with the quadratus lumborum muscle. The third surface looked towards the abdominal cavity and its contents, and so may be described as the visceral or antero-external surface. These three surfaces were separated from each other by definite *borders*. Thus the mesial and dorsal surfaces were separated by the thick and rounded postero-internal border, which was very definite, and ran from end to end of the kidney. It occupied the angle between the psoas and quadratus lumborum muscles. The antero-internal border separated the mesial from the visceral surface. In its middle part it was greatly interrupted and deeply notched by the hilum. The external border was fairly smooth, convex in general outline from above downwards, and by pressure of surrounding parts was reduced to a somewhat thin edge separating the posterior from the antero-external surface. The mesial surface was slightly concave in the antero-posterior direction, whereby it expressed its contact with the convexity of the psoas muscle. Towards the lower end of this surface, a slight groove indicated the passage of the ureter from the hilum at the antero-internal border across the mesial surface as it travelled obliquely backwards and downwards to reach the front of the quadratus lumborum muscle.

The dorsal surface which rested upon the front of the quadratus muscle was considerably indented on its inner portion by the transverse processes of the first and second lumbar vertebræ. Higher than these markings there was a faint indication of pressure from the lig. arcuatum externum. Further, this surface showed several narrow and shallow grooves running downwards and outwards from the level of the postero-internal border, and these indicate the positions of vessels and nerves which lie between the kidney and the quadratus lumborum muscle.

The visceral or antero-external surface being directed towards certain of the other visceral contents of the abdomen, received impressions which record the special relationships of the kidney to these organs.

The inferior extremity of each kidney presented certain common features. Thus, in shape it formed a pyramid presenting three faces, each of which was continuous with one of the primary surfaces of the body of the organ, but the antero-

external surface of the body sloped abruptly backwards as it became continuous with the corresponding pyramid face, so that the latter was really directed downwards and forwards. The pointed lower end of the kidney was therefore in a line with the postero-internal border.

The superior extremities of the two kidneys differed distinctly from each other. On the *right* side the three primary surfaces of the body of the organ faded imperceptibly into a thin convex border continuous with the antero-internal and the external borders. The postero-internal border ran into this upper margin upon its hinder aspect. The upper end of the *left* kidney presented a flat or slightly convex triangular area, whose rounded and thickened edges corresponded to the three primary renal surfaces. In other words, it presented the blunted end of the prism.

While it would be unsafe to dogmatise regarding the precise visceral relations of the two kidneys under observation, yet there is evidence to substantiate the main features of these relationships in this particular 'subject.'

Thus the *right* kidney, by its flattened upper end and its smooth antero-external surface, exactly expressed its position between the diaphragm and the liver. Anterior to and just below the hilum there was evidence of pressure applied by the second part of the duodenum, while the pointed inferior end of the organ, as well as the facet upon its lower aspect, indicated its position as wedged in behind the upper part of the ascending colon.

With regard to the left kidney, there was no difficulty in associating its lower end with the interval behind the upper part of the descending colon. Similarly, the left end of the pancreas may be referred to the anterior aspect of the hilum and the surface adjoining, although there was no descriptive facet in this position.

The area to be associated with the spleen—so far as these organs under consideration are concerned—was not similar to that of His' models, or to a figure given in *Quain's Anatomy* (*loc. cit.*), because the renal surface of the spleen was flat and extensive, and therefore could not be fitted to the outer border of the kidney, as in the cases quoted. In the specimen before

us the spleen rested upon and left its impression upon the larger part of the antero-external surface of the kidney in its outer and upper portion. Internal to the position occupied by the spleen, and above that covered by the pancreas, only a very small area of the antero-external kidney surface was available for relation to the cardiac end of the stomach, an area which was much smaller than that figured in His' casts. Below the level of the spleen and pancreas the kidney adapted itself partly to the posterior aspect of the splenic flexure of the colon, and partly to the posterior aspect of the upper end of the descending colon, behind which its pointed lower end was wedged.

The antero-external surface of each kidney, just below the hilum, presented relationship to the ileo-jejunal coils of the small intestine. The upper end of the left kidney, in conjunction with the adjoining surface of the spleen, adapted itself to the under surface of the hinder part of the diaphragm.

The Suprarenal bodies. — Adrenals cannot be named 'suprarenal' on both sides. Each lay in relation to that part of the antero-internal border of the kidney immediately above the hilum. Each adapted itself to the shape of this border, and extended upwards from the hilum to the inner part of the upper end of the kidney. The lower end of the left suprarenal (adrenal) was larger than its upper end, while on the right side the larger part of the suprarenal (adrenal) was directed upwards and inwards in a pointed manner towards the mesial plane where it rose higher than the upper end of the kidney, besides being somewhat more flattened than on the left side. Each suprarenal (adrenal) body presented three surfaces (separated by well-defined borders), and two rounded ends—an upper and a lower. The surfaces were the outer, by which each was in contact with the kidney; the anterior, by which on the *right* side it bore relation to the liver, and on the *left* side, to the stomach; the mesial, which was continuous with the mesial surface of the kidney, and by which each was in contact with the psoas muscle or the adjacent part of the diaphragm.

The *spleen* differed considerably from the shape presented in His' cast. On the other hand, it showed in an adult organ an exact counterpart of the appearances recorded in Professor Cunningham's cast of the young spleen. It is worthy of note

that the lower and hinder part of its diaphragmatic surface showed two shallow costal grooves. The lower of these was in direct apposition with a similar groove on the posterior surface of the left kidney, and from this fact the groove in question was probably formed by the last rib, which would indicate a slightly lower level for the spleen than is usually described.

The *pancreas* corresponded to current descriptions as regards the shape and position of its head and neck. The body had the well-defined prismatic outline. Its inferior surface, which is described as "narrow," was in this instance about half the width of the anterior or posterior surfaces, *i.e.*, it was $\frac{7}{8}$ in. in its widest part, although towards the right and left ends it was considerably less than this measurement. It seems to me, therefore, that the inferior surface is best described by Cunningham, who says, "it varies greatly in extent,"¹ and that the term "narrow," employed by Quain,² is not sufficiently descriptive. The widest part was a flattened concave, formed by contact with the termination of the duodenum, to either side of which the surface became narrower. This pancreas also showed very distinctly that the greater part of the organ was placed to the left of the mesial plane.

The *liver* was of fairly normal dimensions. The right and the anterior surfaces corresponded to the descriptions, except that both of these surfaces were indented by ribs and costal cartilages. The right lateral ligament was not found in relation to the free border of the right surface as in His' cast, but was situated considerably higher in relation to the superior surface. Perhaps the most pronounced feature of the organ consisted in the disposition of the surfaces usually described as 'posterior' and 'inferior.' Practically, these surfaces formed one region, because the 'inferior' surface was almost entirely directed backwards, and the larger part of the 'posterior' surface looked upwards. In consequence of these modifications in the direction of the surfaces, there was a further modification in the disposition of the peritoneum. Thus the non-peritoneal area of the right lobe was almost entirely directed upwards, and the liver presented a peritoneal area above the level of the upper end of the

¹ Cunningham, *Manual of Practical Anatomy*, vol. i. p. 496.

² *Loc. cit.*, p. 141.

right kidney. Further, the lower half of the right suprarenal (adrenal) was covered by a peritoneal layer, while its upper half was in relation to the posterior surface of the inferior vena cava and the adjacent non-peritoneal surface of the liver. The renal impression was much more extensive vertically than that given in His' cast. It corresponded to the whole of the antero-external surface of the kidney, with the exception of the colic area at its pointed lower end. As already indicated, the lower part of the suprarenal (adrenal) impression was covered by peritoneum. The impression formed by the inferior vena cava was separated from that caused by the second part of the duodenum by a somewhat low transverse ridge, while a similar low ridge running almost vertically separated the suprarenal and renal impressions from those for the duodenum and inferior vena cava. At the point where those low ridges intersected each other the liver substance presented a *rounded tubercle*—the renal tubercle—corresponding in position to the front of the upper part of the hilum of the right kidney.

The Spigelian lobe was narrow, and tended to be convex rather than concave, while its caudate prolongation lay in front of, and was grooved by, the inferior vena cava.

The quadrate lobe was of normal dimensions and arrangement, except that the inclination of its surface was somewhat more backwards than downwards. A low transverse ridge near its free border divided its surface into a large posterior area for the first part of the duodenum and a small anterior area for the transverse colon.

The left lobe was sharply defined. It presented the left lateral ligament in relation to its free margin. The concavity on its gastric aspect was markedly directed backwards, and occupied nearly the whole of the abdominal aspect of the lobe, being separated from the umbilical fissure and the fissure for the obliterated ductus venosus by a low ridge, in which the most projecting part—representing the tuber omentale—was situated opposite the left end of the transverse fissure. A well-marked concavity indicated the position for the cardia. Looked at, as a whole, the liver in question was situated *in front of* certain abdominal organs rather than *above* them.

In many of the appearances which these organs presented

they repeated conditions characteristic of certain foetal stages, while in others they illustrated progressive forms when placed in comparison with the corresponding organs of the foetus, of the young child and of the adult.

For example, in a foetus of seven months, the kidneys, although their lobulated nature is still evident on their surface, present the three surfaces characteristic of the adult, but less definitely defined by borders. In Cunningham's casts of the kidneys of the young child, while the surface lobulation has disappeared, yet the division into three surfaces¹ is still better defined, as well as the evidence of facetting by pressure from contiguous organs. In the foetus, the antero-external surface of the left kidney is divided into two important areas by the position of the pancreas. Above the level of the pancreas the stomach is only to a very slight extent, if at all, in contact with the kidney, while both above and external to the pancreas the splenic facet forms a distinct surface. Below the level of the pancreas, the postero-inferior aspect of the stomach and the ileo-jejunal coils leave their imprint on the kidney, but are separated from each other by the attachment of the transverse meso-colon. The colic impression is carried well towards the outer limit of the lower end of the kidney. In the young child these conditions are somewhat modified by the growth of parts, and the stomach does not touch the kidney below the level of the pancreas, nor can it be said to do so to any appreciable extent above the level of the pancreas, but the splenic, pancreatic, and colic facets remain distinct features. His' cast of the adult left kidney shows a large gastric area above the pancreas, and quite a narrow splenic facet relegated to the outer border of the kidney. In the adult specimen in my possession the appearances harmonise with those of Cunningham's cast of the child, and present a large splenic facet, but only a very limited area for association with the stomach.

The antero-external surface of the right kidney in the foetus is in contact with the liver, the ileo-jejunal coils, and the caecum and vermiform, since these latter have not yet descended to

¹ Professor Cunningham describes what I have called the mesial and dorsal surfaces as internal and external districts of the posterior surface of the kidney. Vide *Jour. Anat. and Phys.*, vol. xxix. p. 501.

their permanent positions. In the child and in the adult, the hepatic flexure of the colon is substituted for the cæcum and vermiform, while the second part of the duodenum assumes its position in front of the hilum.

The suprarenals (adrenals) of the fœtus and of the child are suprarenal in position, whereas in the adult they have not only diminished in relative magnitude, but they have lost their suprarenal position, and to a large extent have become internal to the upper ends of the kidneys. In the fœtus each suprarenal presents three surfaces—mesial, posterior, and antero-external—surfaces which correspond to those of the kidney. In addition, each has a pointed apex and a flattened base resting upon the upper end of the kidney.

In the child, traces of this arrangement are still found, but the posterior surface has dwindled. In the adult the posterior surface has disappeared. In the fœtus the antero-external surface of the right suprarenal is partly covered by peritoneum, and impresses its position upon a peritoneal surface of the right lobe of the liver. To a very slight extent this is also the case in the young child, but in His' cast of the adult organ the *impressio suprarenalis* is confined to the non-peritoneal area of the liver, whereas in the adult organ I have been describing it forms a marked facet upon the adjoining peritoneal area of the liver.

The corresponding surface of the left suprarenal of the fœtus is in contact both with the stomach and the spleen, although separated from both by peritoneal membrane. In the young child the same condition of parts persists, whereas in the adult the suprarenal has lost its immediate relationship to the spleen.

The spleen of the fœtus presents a large phrenic surface, and in addition, gastric, pancreatic, colic, renal, and suprarenal facets, all of which are definitely distinguished from each other by low ridges. In the child, the large renal facet is continued without interruption into the small area which is associated with the suprarenal body. In the adult, the spleen has lost its contact association with the suprarenal, while retaining its other relations, and extending, in particular, its area of contact with the antero-external surface of the left kidney.

Of the fœtal liver, only a small part of the left lobe looks

downwards, and all the rest of the abdominal aspect is for the most part directed backwards, with but slight obliquity. As the right and left lobes are of nearly equal size, the organ resembles a wedge let down from the diaphragm between the viscera and the anterior abdominal wall, with space for the accommodation of viscera behind the liver. This space diminishes in an upward direction, but still permits the suprarenals, the spleen, and the cardiac end of the stomach to ascend almost to a level with the upper aspect of the liver. The abdominal surface of the left lobe presents the gastric impression (almost entirely directed backwards) and two projections, viz., the tuber omentale, and another in relation to the gastro-colic omentum, immediately beyond the antero-inferior curvature of the stomach. A groove between these two tubercles indicates the position of the pyloric portion of the stomach, while another groove in front of the anterior tubercle results from the pressure of the transverse colon, a knuckle of which fits into the notch behind the umbilical vein. In the liver of the child, as well as in His' cast of the adult liver, only the tuber omentale and the pyloric groove remain, while a very distinct inferior aspect is presented by this lobe. In the adult liver I have described the general direction of this surface is decidedly backwards, but neither of the tubercles nor the pyloric groove is well defined, since a low broad ridge occupies the positions corresponding to them.

In the foetus, the abdominal surface of the right lobe receives impressions from many organs. On the extreme right the renal and suprarenal impressions are well marked, and separated from other impressions by a ridge in which a prominent blunt tubercle indicates the position of the hilum of the kidney. Immediately in front of the hilum, and in relation to the neck of the gall-bladder, the liver is indented by the first part of the duodenum. Anterior to the duodenum, the transverse colon grooves the liver transversely from the notch behind the umbilical vein across the surface of the gall-bladder to the ridge which limits the impression of the right kidney. Anterior to the transverse colon, the region of the quadrate lobe is indented by certain of the ileo-jejunal coils, while others of these coils, together with the vermiform appendix, overlap the thin

lower border of the right lobe, and indent the lower part of its anterior surface.

In Cunningham's cast of the child's liver, the right lobe still affords evidence of its intimate association with many of the above parts. This is especially interesting in connection with the deep notch behind the ligamentum teres, where, more particularly in relation to the quadrate lobe, we are warranted in associating some knuckle of transverse colon, as well as with the wide fossa in front of the fundus of the gall-bladder. These two impressions are deep in comparison with that for the hepatic flexure of the colon, which, although distinct as an area, is convex instead of being depressed.

In the adult liver the renal and suprarenal impressions vary according to the relative size of these organs. His' cast does not show the tubercle which I have described as situated in relation to the hilum of the right kidney, both in the foetus and in the adult. The notch associated with the umbilical vein has disappeared in the adult through the extension of the quadrate lobe; but whereas, in His' cast, this lobe is indicated as a flattened concavity, in the specimen I have described it presented impressions for the first part of the duodenum, and for the transverse colon, the latter being definitely continued superficial to the gall-bladder, to blend with the impression for the hepatic flexure, an impression which was flat rather than concave as in His' cast. This indentation of the quadrate lobe by the transverse colon would seem to indicate that in some cases at least the transverse colon is pushed upwards by the ileo-jejunal coils, and does not always occupy the festooned position which is usually ascribed to it.

In His' cast, the Spigelian lobe is indicated as a flattened concavity, while in Cunningham's cast of the child's liver, as also in the foetal liver and the adult organ I have described, it presented a narrow and slightly elevated convexity, tending to be flattened by pressure against the decussating muscle fibres of the hinder part of the diaphragm.

THE LATERAL THORACIC BRANCH OF THE INTERNAL
MAMMARY ARTERY. By DAVID HEPBURN, M.D.,
Lecturer on Regional Anatomy, University of Edinburgh.

THE occasional occurrence of a lateral branch of the internal mammary artery is known, and in some anatomical text-books it



is referred to among arterial abnormalities ; yet, notwithstanding its large size when present, no illustration of the vessel is given either in Tiedemann's *Tabulæ Arteriarum Corporis Humani*, or in Quain's *Anatomy of the Arteries of the Human Body*, or in

Lizars' *Anatomical Plates*. For this reason a short account of the abnormality, with an illustration showing the position and principal relations of an instance of this condition which occurred in the University Practical Anatomy rooms, may not be out of place. The vessel in this case appeared on the right side of a female subject, in which both internal mammary arteries were well developed, besides being of apparently equal size. It arose from the parent trunk above the level of the first rib, to the inner side of the scalenus anticus muscle, and descended downwards and outwards between the costal pleural membrane and the inner aspects of the upper four ribs, with their corresponding intercostal structures. Its general position was slightly in front of a line equidistant between the sternum and the angles of the ribs. In size it was slightly less than the vessel from which it sprang. As it descended it formed frequent anastomoses, by small collateral branches, with the intercostal arteries. In the fourth interspace it terminated by dividing into two branches which entered the substance of the internal intercostal muscle.

The condition of the injection (which was otherwise very complete and detailed) appeared to indicate a diminution in the size of the intercostal arteries of the upper four intercostal spaces. Companion veins were observed in association with this irregular artery. They joined the upper end of the internal mammary vein.

It may be mentioned that the eighth right costal cartilage was directly attached to the margin of the sternum.

The interest and value of this abnormality are probably surgical rather than morphological, although it presents some points of resemblance to the unnamed ascending branch of the deep circumflex iliac artery.

EXAMPLE OF A LARGE OPENING BETWEEN THE
TWO AURICLES OF THE HEART, UNCONNECTED
WITH THE FOSSA OVALIS. By T. WARDROP GRIFFITH,
*Professor of Anatomy, Yorks. Coll., Leeds; Senior Assist. Phys.,
General Infirmary at Leeds.*

THIS specimen has been in the museum of the medical department of the Yorkshire College for many years, but, so far as I know, has not been described, and I am indebted to our curator, Dr Trevelyan, for permission to remove it from its jar for examination.

The heart appears to have been of about normal size, possibly slightly hypertrophied. There was some thickening of the portion of mitral valve left, with shortening of the curtain and amalgamation and thickening of the chordæ. From the appearances of the remains of the tricuspid, pulmonary, and aortic valves, these were probably normal.

The area of the fossa ovalis was large, and presented some reticular bands at the lower part, representing probably the remains of the Eustachian valve. The foramen was quite closed.

A large aperture was seen forming a communication between the two auricles of the heart. This was oval in outline, about $1'' \times \frac{3}{4}''$, and with its long axis running downwards and forwards in the natural position of the heart.

It was situated a quarter of an inch in front of the fossa ovalis, and about one inch above and in front of the opening of the coronary sinus. Its anterior margin was formed by the meeting behind and above the interventricular septum of the auricular aspects of the anterior segment of the mitral, and of the septal and anterior segments of the tricuspid valves.

The pars membranacea septi ventriculorum was very small, the fleshy septum of the ventricles extending upwards and backwards to the anterior part of the postero-right aortic segment, instead of, as usual, only to about the middle of the anterior segment.

If we accept the views of Born as to the development of the

interauricular septum, we would see in this specimen a failure on the part of his primary septum to meet the endocardial cushions which had divided the common auriculo-ventricular aperture into mitral and tricuspid orifices.

It is interesting to note that normally the auricular septum is somewhat thin in the position occupied by this abnormal aperture. The crista terminalis of His, forming a strong muscular band, can be traced on to the auricular septum between the fossa ovalis and the orifice of the coronary sinus, and then seen to form a well-defined thickening along the anterior margin of the former, and it is in front of this band that the auricular septum appears to me to be usually thin in many instances.

In 1881 Dr Norman Moore showed at the Pathological Society an example of the same congenital anomaly, and in commenting on its rarity said that only two or three cases were on record.

ON AN ATYPICAL CASE OF "STRONG" CURRENT IN
PFLÜGER'S LAW. By DAVID FRASER HARRIS, M.D.,
C.M., B.Sc. (Lond.), F.R.S.E., "*Muirhead*" Demonstrator of
Physiology in the University of Glasgow.

THE occurrence of a phenomenon which does not agree with the classical descriptions of it is always interesting: if observed only very rarely, some purely local disturbing influence can usually be discovered to explain the case away; but when the aberrant phenomenon recurs again and again under different conditions, it may justify being, at least, put on record.

Year after year, in our Class of advanced Practical Physiology, on the day on which "Pflüger's Law" came to be worked out, I find in my diary of notes and comments on the daily exercise such entries as, "Break descending strong—atypical"; then the next year, "Break descending strong, not according to text-books"; and once more, "Break strong descending, again equivocal."

The case alluded to is, that whereas almost all the text-books give "Rest" as the result of breaking a "strong" current descending in the nerve of a nerve-muscle preparation, in the majority of cases in which I have seen the experiment performed, the result was a slight contraction in the muscle.

This atypical result kept on recurring with such persistence that I latterly warned the class not to be disappointed if the case of the "Break strong descending" did not come out exactly as described by the authorities.

Now, the attendant conditions varied from year to year, in that the workers were different pupils; the frogs used were, of course, of a different batch; the degree of the freshness of the nerves by no means the same in each experiment; the current intensity varied from 3.5 to 7 ampères (voltage about 2); and yet the result came out, year after year, different from the generally accepted result, and the nature of the difference was always the same.

Further, all the other cases of the Law for "strong" currents were quite in accordance with the classic formulæ; the Make

and Break of strong ascending gave Rest and Contraction respectively, and the Make of strong descending, Rest, exactly as in the hands of all other workers; this is, as it were, an internal or physiological proof that our workers were dealing with the "strong" current of Pflüger, and not his "medium," in the various observations in which the aberrant case continued to recur.

Considering the diagram of the case (fig. 1), we have + and — the poles of the strong descending constant current; the curve A below the line (which represents both the nerve and the "level" of its normal excitability) indicating the relatively large peripolar region of anelectrotonic depression of the excitability which is established at Make; and K, the curve above the line, representing the relatively small peripolar region of katelectrotonic increase of the excitability also established at Make;

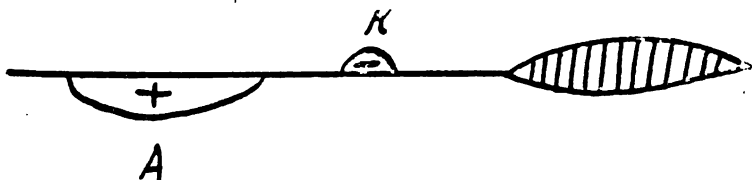


FIG. 1.

which hyper-normal excitability is, indeed, *ex hypothesi*, the effective stimulus for the contraction which occurred on closing the current.

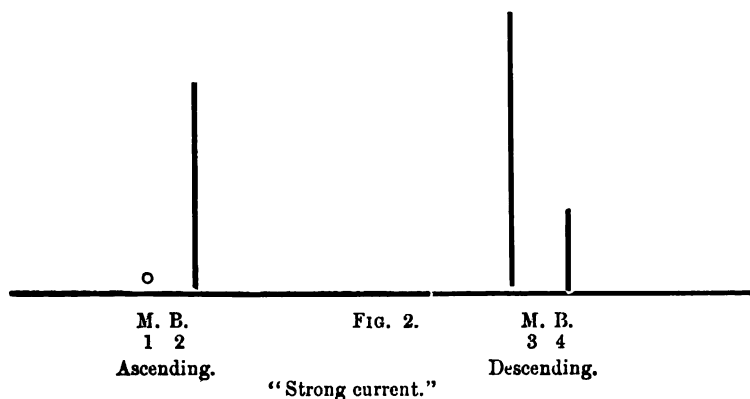
The conditions, therefore, just before Break are :—

1. Near the muscle an area of *super*-normal excitability and conductivity; and
2. Farther from the muscle a larger area of *sub*-normal excitability and conductivity.

But at Break changes occur; for, according to the working hypothesis which explains all the other cases, (1) the greater-than-normal excitability and conductivity in the region K returns to the normal level, so that the conductivity in the area K is at least not less than normal, and (2) the relatively large area of less-than-normal excitability and conductivity returns suddenly to the normal, which is, *ex hypothesi*, a stimulus (being an *increase* of excitability from below normal to normal), and this anelectrotonic-return-stimulus occurring in

a large region, and finding no resistance in the kathodic peripolar area, is propagated to the end-plates, and a contraction occurs.

Our tracings showed it always to be a less vigorous contraction than that produced by the Make of a strong descending current, which is quite as it should be, theoretically, inasmuch as at the Make, the stimulus is a myopolar katelectrotonic increase of excitability, which must always be a more effective or irritating stimulus than the return-to-normal of the anelectrotonic diminution of the excitability occurring, in no matter how large an area of nerve. (See fig. 2.)



[Here the contractions at Make and Break are recorded on a stationary surface. “4” in the figure is “Rest” in the accepted statements of Pflüger’s Law.]

The usual explanation of no contraction in the case of the Break of a strong descending current is, that the anelectrotonic stimulus has to pass through a region of diminishing conductivity (K), but this is only a *relative* diminution; it is a fall in degree of conductivity from a state of greater-than-normal to normal, and therefore no real or positive resistance. But, again, the fact that the area A is one of diminished conductivity does not enter into the question, for the conductivity in A is only diminished while the current is passing; the instant it is broken, the conductivity undergoes relative increase, *pari passu* with that of the excitability, from less-than-normal to normal; this molecular swing-back being the stimulus which is propagated,

not through a region of increased resistance, but through a region (A) which, if not quite normal as to its conductivity, is with extreme celerity becoming so.

We have, however, positive proof¹ that although the excitability of a portion of nerve has been abolished, the conductivity of that same part is still retained; therefore if the return (from anodic depression) of both these properties be not simultaneous, the *conductivity* is almost certainly the first to be re-established.

Further, Waller² considers that Biedermann's observation—"whereas excitation starts from the precise point with which the kathode is in contact, it starts from an area at some distance surrounding the anode"—is applicable to nerve as well as to muscle. This supports the view that the Break stimulus is the return-to-normal of the excitability over the whole area A simultaneously; this being itself stimulating, it sets up an impulse which is propagated *from* the area A peripherally. In other words, the peri-anodic area is itself the site of origin of an impulse which, being homogeneous, and produced at the same instant throughout all points of the area A, need not be conceived as especially travelling from point to point throughout that area.

Again, Waller,³ in discussing the applicability of Pflüger's Law to human nerves, says (page 58)—"Unless an excessively strong current is used, kathodic opening produces no effect"; but the case of the reservation is, I believe, the case before us.

It is a case of "kathodic opening" when you break a descending current, in which, therefore, the kathode is myopolar; and without doubt our workers often used a current which, relative to the nerve they were dealing with, was "excessively strong."

Reverting to figure 2, which is a *facsimile* of a tracing obtained, the four results are, when compared *inter se*, quite what we should expect, for, of all the stimuli, the establishment of myopolar katelectrotonus must be the most irritating, there-

¹ Grünhagen's Experiment, *Outlines of Practical Physiology*, p. 256; Stirling, 3rd edition, 1895, London.

² *Human Physiology*, p. 327, London, 1893.

³ *Exercises in Practical Physiology*, part iii., London, 1897.

fore (3) is the highest contraction; next, in relative order of efficiency, is the disappearance of a large area of myopolar anelectrotonus, and thus (2) is the next highest: (1) yields no contraction, because the establishment of a small centropolar area of katelectrotonus does not produce a stimulus powerful enough to be propagated through the large myopolar area of the increased intervening resistance: (4) is the case we are examining. "Rest" is the classical result; but I venture to suggest that the occurrence of "contraction" here, which we have frequently obtained, can be justified on the same theoretical grounds as those on which all the other cases are so consistently explained.

Biedermann,¹ in his historical resumé of the subject of electrical excitation of nerve, notices the case we are discussing. In the table of the Ritter-Nobili Law of Contraction, we evidently have the case alluded to as Ritter's "fourth" stage and Nobili's "second," thus:—

Ascending current, . . .	{	Make = 0 or weak contraction.
	{	Break = contraction.
Descending current, . . .	{	Make = contraction.
	{	Break = weak contraction.

More explicit is Biedermann's presentation of Pflüger's Law, thus:—

Strong ascending current, .	{	Make = 0.
	{	Break = contraction.
Strong descending current, .	{	Make = contraction.
	{	Break = 0 or <i>weak contraction</i> .

With this statement of the formula I fully agree, for the possibility of either result in the last-mentioned case should undoubtedly be remembered; but I believe with very strong currents, "weak contraction" is the rule, Rest the exception.

¹ *Electro-Physiology*, vol. ii. p. 135, English translation, London, 1898.

VARIATIONS IN THE HUMAN TOOTH-FORM AS MET
WITH IN ISOLATED TEETH. By A. E. TAYLOR, B.A.
Downing College, Cambridge.

IN order to test the utility of the material which is liable to accumulate during the practice of dentistry, such as drawn teeth, for purposes of research, I obtained of a dentist a quantity of drawn teeth, and subjected them to examination. There was considerable difficulty experienced in the identification of some of these, owing to the fact that, in addition to variations whereby some teeth simulated the characters of others, *eg.*, lower molars with three fangs, the distinguishing features of all were more or less affected by caries. Of very great service for purposes of identification was an examination of the position, character, and inclination of the friction facets, as recommended by Professor Macalister: these facets were often so small and insignificant as to demand patient search with a lens before they could be discovered; on the other hand, in rare cases the tooth would be worn almost to the gum; examination in this way by the lens revealed the fact that the enamel is very frequently marked by minute cracks or fissures, generally in a vertical direction, but sometimes horizontally at the boundary of the grinding surface; these minute cracks being in all probability the result of drying.

In addition to the data shown in the table below, my examination showed:—

Of the upper central incisors 14 per cent. exhibited a swollen talon (in some cases marked off from the crown by a slight groove), simulating a lingual cusp.

Of the upper lateral incisors 12 per cent. showed a swollen talon.

Of the first upper premolars in 45 per cent. the two fangs were fused into one. These teeth exhibited every phase of a gradual transition from a single fang without sign of division, to two perfectly formed and separate fangs, as in the following series:—

Of the first lower premolars 84 per cent. had a single fang.

Of the second upper premolars 14 per cent. had a double fang, the remainder had a single fang.

Of the second lower premolars 7 per cent. had a double fang, the remainder possessed a single fang.

Of the first upper molars all the fangs were fused in 5 per cent. of cases, and two of the fangs were fused in 14 per cent. ; of these, the two external fangs were fused in 8 per cent., the internal and postero-external fangs were fused in 6 per cent., but no case was met with of fusion of the internal and postero-

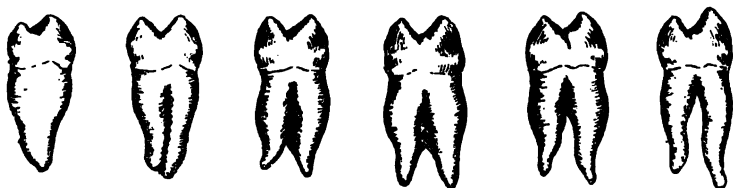


FIG. 1.—Series of first right upper bicuspid teeth, viewed from the distal side.

external fangs leaving the postero-external fang free. In most cases four cusps were present, two external and two internal, but occasionally there was a fifth cusp at a bifurcation, either of the groove separating the postero-external from the postero-internal cusp, or more rarely at a bifurcation of the groove separating the antero-external from the antero-internal cusp ; in one case the fifth cusp appeared in the centre of the others.



FIG 2.—Normal. Anterior 5th cusp, post. 5th cusp, middle 5th cusp.
View of the crowns of a series of upper right first molar teeth.

There was in this case, as in the bicuspid, and also in other molar teeth, every gradation to be seen between total fusion of all the fangs and perfect separation, as in the following series:—

In the first lower molars, all the fangs were fused in 3 per cent. of cases ; there was a separate, third, internal fang in 3 per cent. of cases.

Name of Tooth.	Dimensions.	Length, in centimetres.	Breadth (i.e., labio-lingual length), in centimetres.	Thickness (i.e., proximo-distal length), in centimetres.	Length of Longest Fang, in centimetres.	Height of Crown, in centimetres.	Distance between External and Internal Roots, in centimetres.	Distance between Two External Roots, in centimetres.	Percentage of Cases in which the Fangs were Curved.	Number of Teeth examined.
Upper central incisors,	Greatest,	2.7	1.9	1.0	6 % slightly	15
	Least,	1.9	...	...	1.1	.7	...	...
	Average,	2.3	...	...	1.45	.75	...	...
Lower central incisors,	Greatest,	2.5	1.7	.9	4 % slightly	22
	Least,	1.7	...	...	.9	.5 (worn)	...	...
	Average,	2.07	...	...	1.45	.7	...	...
Upper lateral incisors,	Greatest,	3.0	2.0	1.0	6 % slightly	16
	Least,	1.8	...	...	1.9	.7	...	...
	Average,	2.04	...	...	1.47	.8	...	...
Lower lateral incisors,	Greatest,	2.8	1.8	1.0	5 % slightly	16
	Least,	1.9	...	...	1.2	.4 (much worn)	...	...
	Average	2.0	...	...	1.4	.7	...	...
Upper canines,	Greatest,	3.0	2.0	1.0	30 % strongly	10
	Least,	2.3	...	...	1.5	.7	...	...
	Average,	2.7	...	...	1.8	.9	...	...
Lower canines,	Greatest,	2.7	1.8	1.0	10 % slightly	10
	Least,	2.0	...	...	1.4	.5 (worn)	...	...
	Average,	2.3	...	...	1.5	.7	...	...
Upper first premolars,	Greatest,	2.9	1.1	.7	1.8	1.0	6 % slightly	49
	Least,	1.9	.7	.5	1.1	.6	...	...
	Average,	2.3	.9	.6	1.4	.8	...	...

In the second upper molars, there were three fangs in 65 per cent.; external fangs fused in 35 per cent.

In the second lower molars, fangs fused into one in 1 per cent. of cases.

In the upper wisdom teeth, fangs in a single mass in 90 per



FIG. 3.—Right upper first molar tooth, seen from the distal surface.

cent.; mass separating into separate fangs at its lower end in 10 per cent. of cases.

In the lower wisdom teeth, the fang mass separated at its lower end into separate fangs in 20 per cent. of cases.

Amongst all the teeth examined, there was only one supernumerary tooth: this was flattish, pip-shaped, with a single fang and the rudiments of three cusps; it was deeply indented below the crown on one side, 1.2 cm. long, .7 cm. wide, and .4 cm.



FIG. 4.—View on the four different sides of a supernumerary tooth.

thick. It was extracted from between the molar and bicuspid teeth on the right side of the upper jaw of an adult male about 40 years of age.

Eight hundred and twenty-eight teeth were examined; there were about a quarter as many more of crownless stumps, chiefly of molars, and about forty milk teeth of all kinds; but this did not seem to me a large enough number to render the examination of them of any value.

ABSTRACT OF REMARKS ON THE BRAIN-CAST OF
PITHECANTHROPUS ERECTUS.¹ By EUG. DUBOIS.

THE speaker announced the discovery, during the past year, of another tooth referable to *Pithecanthropus erectus*, in further excavations at Trinil in Java, made under the speaker's direction. This tooth is remarkable as being the second left *lower* premolar, the tooth already found having belonged to the upper jaw. The fact that it was discovered in that part of the sandstone formation immediately adjoining the site of the other remains of *Pithecanthropus erectus* affords an additional argument in favour of the individual identity of origin of all.

In the next place, the results of the examination of over one thousand human femora from different races were summarised, the conclusion arrived at being that the femur of *Pithecanthropus* really does show a slight divergence, indicative of a lower limb, which, while rendering its possessor capable of the bipedal mode of locomotion, still retains some vestiges of adaptation to an arboreal existence.

After these preliminary remarks, the speaker proceeded to the consideration of the now well-known calvaria and the brain (as founded upon the cast of the interior of the calvaria). He declared that minute investigation of the value of the method of superposing profile lines led him to reject this as a reliable means of comparison of cerebral development between man and the apes. Since arriving at this conclusion, the speaker's researches have dealt very largely with the capacity of the calvaria, and with the form of the brain, as presented by a cast of the interior of the same, both of which lines of investigation have been rendered possible by the careful removal from the calvaria of the stony deposit previously contained therein. The salient features of the brain-cast thus obtained may be summed up as follows:—

The narrowness of the brain in the frontal region and the

¹ Read at a General Meeting of the Fourth International Congress of Zoology, Cambridge, 26th August 1898. Communicated by W. L. H. Duckworth, M.A., Jesus College, Cambridge.

strongly-marked convolutions of this part are considered to be individual departures from a slightly different type, which might be considered normal, the departures in question being consequent on premature obliteration of the metopic (interfrontal) suture, which is actually indicated by the scapho-cephalic (trigonocephalic) character of the frontal region of the calvaria.

Other noteworthy features of the brain revealed by the brain-cast are: the close approximation to the human form of brain presented by the fact, that the greatest transverse diameter of the hemispheres is found at a point corresponding to the junction of the anterior $\frac{2}{3}$ with the posterior $\frac{1}{3}$ of their length. With the exception of certain small new-world monkeys, this feature is unknown among apes, the latter possessing brains whose maximum diameter is situated much more posteriorly. The importance of this character is revealed by the consideration that it is associated, firstly, with a forward displacement of the insertions of the sterno-cleido-mastoid muscles; and secondly, with a more anterior position of the occipital condyles, whence follows the indication of an animal form which had assumed the erect attitude. As regards the frontal convolutions, the degree of development of the inferior frontal convolution is very marked: its form approaches that of man; and though its superficies is less by one-half than in the latter, it is double that of the largest brain of an anthropoid ape. This fact suggests a certain degree of the faculty of speech in *Pithecanthropus erectus*.

The speaker now bases his appreciation of the relative cerebral development of various specimens on the comparison of brain-weights measured directly, or deduced from records of cranial capacity. The method of estimating the relative development of the brain has been brought to a high pitch of accuracy by a method of the author's (which has been described in detail in two previously published papers).

An estimation of the brain-weight of *Pithecanthropus erectus* was arrived at in the following manner:—The calvaria was so manipulated as to yield an accurate determination of that portion of the cranial cavity available. From the figure 570 c.c., as measured with water above the transverse plane between the frontal pole and the uppermost border of the sulcus transversus, thus obtained, the total cranial capacity was determined by an extension of the

same method of observation to complete skulls of man and of apes (the procedure was described in detail). Finally, the brain-weight itself was deduced from the figure representing the cranial capacity. The capacity is thus found to be about 850 c.c., and the brain-weight about 750 gm. These figures approximate *Pithecanthropus erectus* to man much more distinctly than to any anthropoid ape; for while human crania of admittedly normal character have yielded capacities of 1000 c.c., and even of 930 c.c., anthropoid apes, on the other hand, have yielded no figure higher than 600 c.c. (when duly corrected).

It remains, however, to exclude as far as possible the question of individual variation, as possibly modifying the case of *Pithecanthropus erectus*. From the consideration of data relating to human cranial capacities, and records of individual variations relating to about two thousand different determinations (of all races), the range of variation for such a species as *Pithecanthropus erectus* is justifiably considered to be from 710 c.c. to 1060 c.c., but at either of these extremes *Pithecanthropus* would still remain in the (intermediate) position already assigned to it by the more direct computation of 850 c.c. At the same time, according to these figures, *Pithecanthropus erectus* is not absolutely excluded from the ape-tribe or from mankind. It must, however, be taken into consideration that the size of the brain depends to a large extent upon that of the body, whose influence may be stated in the following way:—In man, as in lower animals, large individuals have larger brains than have smaller ones; and by a method published elsewhere, the author has arrived at a means of correctly estimating the influence of the size of the body on the size of the brain of mammals and of man. By the application of this method, in the first instance, to man and to the anthropoid apes respectively, it results that, reference being made to the same standard of bulk, man has four times as much brain as anthropoid apes. Further, in the consideration of various races and both sexes of mankind, the variation in this *cephalisation* of the central nervous system does not exceed 10 per cent.; and, in fact, in comparing large numbers of English and German males of the same social class, the difference is less than 1 per cent.

Similar reasoning was then applied to the data available from

the study of *Pithecanthropus erectus*, in such a manner that the encephalisation of *Pithecanthropus erectus* was calculated from the body-weight of the same, as indicated by the dimensions of the femur. The result thus obtained shows that *Pithecanthropus erectus* possessed a brain proportionately about half the size of that of man, and twice the size of that of the average in the large anthropoid apes.

This result, the author contends in conclusion, is the most convincing proof of the perfectly intermediate character of the paradoxical pliocene inhabitant of Java.

At the end of the general meeting, in which Dr Dubois read this paper, the following resolution was proposed by Professor Macalister, and seconded by Professor O. C. Marsh:—

“That, in the opinion of this meeting of the members of the Fourth International Congress of Zoology, the Dutch Indian Government, by ordering the exploration of Trinil, Java, leading to that most remarkable discovery of *Pithecanthropus erectus*, have laid the zoological world under a most weighty obligation, and that the aforesaid members of the Fourth International Congress of Zoology hereby desire to express their fervent hope that these investigations may be continued in the future with the same thoroughness as in the past.”

The above resolution has been adopted by the meeting, and will, in the official way, be brought to the notice of the Dutch Colonial Government.

ON THE CONDITION KNOWN AS 'EPIGNATHUS.' By
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Anatomy in Mason University College, Birmingham.*

SOME little time ago I received from my former pupil, Dr Dudley of Stourbridge, a specimen of the rare condition known as 'epignathus,' which I propose to describe and consider in this paper. The facts of the case are as follows:—The mother was a primipara, and had been seven months pregnant. The auto-site presented no abnormalities save those connected with the tumour, which hung from its widely-open mouth. The tumour consisted of a number of nodules of various sizes, which, taken altogether, composed a mass about twice the size of the child's head. The largest lobe was cystic, and contained a pultaceous semi-fluid substance. Its cavity did not communicate with that of any other part of the tumour. The remaining lobules contained many pieces of bone, none of which could, however, so far as they were examined, be referred to any normal types, also cartilage and muscle. I did not find any teeth in any part of the tumour. One of the lobules protruded through the nostril, for there was but one, the presence of the tumour having prevented the development of the septum of the nose. On examining the oral cavity it was seen that, whilst the anterior part of the hard palate was complete, the hinder was absent, and the tumour itself was attached to the basis cranii by a fibrous stalk. The skull being opened, and the brain, which was in a half-rotten condition, removed, it was found that a probe could be passed down the patent pituitary foramen into the interior of that portion of the tumour which lay nearest to the base of the skull,—the stalk, in fact, being tubular. The cavity thus approached did not communicate with any other part of the tumour, and contained a thick pultaceous substance. The tumour was not in a very satisfactory state for microscopic examination, but a portion was removed from one of the cotyledons, of which preparations were made, and a report kindly given to me by Dr Bolton, who tells me that the fragment has a

cartilage in the centre, which is surrounded by a considerable amount of plain muscular tissue, with many blood-vessels in the looser parts. Outside this, there is hard, loose, coarsely reticular embryonic connective tissue. The character of the epithelium of the surface could not be properly made out. In one of the sections there was found a small nerve-ganglion containing several globular cells, some of which were pigmented, but the examination for nerve-fibres was negative in its results.

The name of 'epignathus' was given to this class of monstrosity by St Hilaire (1), who based his description of it on a single exceedingly imperfectly described case.¹ The definition which he gives of the condition—"Une tête accessoire, très-incomplète et très mal conformée dans toutes ses parties, attachée au palais de la tête principale"—would exclude many cases which properly come into this category; and for this reason, neither name nor definition are satisfactory at the present day. However, as Taruffi's name of 'endoprosopus amorphus' has not, as yet at any rate, found favour with teratologists, the former may be retained, though the latter must certainly be revised. In attempting to give a better definition, it is necessary to find one which will exclude an actual, obvious, though it may be partial, duplicity of the skull (such as was present in the exceedingly interesting case given by Bland Sutton (2)), as also polygnathia,² which, so far as it was known to him, St Hilaire placed in the class Augnathus, near to that with which we are now concerned.

On the other hand, it must include all forms belonging to its class, from the simple hairy polypus of the pharynx to the tumour with fully developed portions of a foetus, for these and the intermediate conditions form, in my opinion, a single group. An epignathus, then, is a congenital tumour, teratoid in its nature, or possessing recognisable parts of a foetus, which is attached within the cavity of the mouth or upper

¹ St Hilaire's complaint as to the description of this case might be applied, unfortunately, to others made public since his day. "Le mode d'implantation," he writes, "l'une des circonstances les plus intéressantes à connaître, est malheureusement l'une de celles que nous ignorons le plus complètement. Que conclure d'une indication aussi vague que celle-ci: *Per aemula vertebrarum corpuscula palato cohaerente monstroso capitis rudimento.*"

² A list of recorded cases of this class will be found in a paper by the present writer in this *Journal*, vol. xxviii. p. 25.

part of the pharynx. Lists of cases of this class have been published by Ahlfeld (3) and Arnold (4), and others have since appeared. I have brought into one table—which is appended to this paper—all the cases which I have been able to come across, in order that they may be readily accessible to future workers. From this list I have excluded at least one of Ahlfeld's cases,¹ because it did not appear to me to come properly into this group. The cases number about sixty, so that the condition may be fairly described as a rare one.² It is certainly curious that it never appears to have been met with by any of the older teratological writers. No one who has seen a case can suppose for a moment that if one had come under the notice of Schenk, Licetus, Licosthenes, or Aldrovandus they would have neglected so excellent an opportunity; yet I have looked through their works without finding any case which can be supposed to be one of epignathus. I have principally been desirous of calling attention to the site of implantation and contents of the tumours in my list. As to the former point, there is considerable indefiniteness in many of the descriptions; but I have endeavoured to refer each to its proper group, so far as the indications permitted.

Of the cases collected, twenty-two are instances of attachment to the palate or to the superior maxillary bone of one or other side, for the presence of the tumour has often caused an almost entire absence of the palate. The next most numerous group, including fourteen cases, is in many respects the most interesting of all. It contains those tumours which are attached to the base of the skull in some manner or another. Sometimes the attachment is merely to the lower surface of the bone or the mucous membrane which invests the upper part of the pharynx. But in some cases (iv., 5, 6, 9, 14)³ the stalk of the tumour is distinctly traceable through the pituitary foramen, whilst in a

¹ That described by Bury, *London Medical Gazette*, vol. xiv. (Ahlfeld, No. 8). The tumour here was attached to the frontal bone, and did not belong to the cavity of the mouth.

² I have also found mention of the following cases, to which I have been unable to refer:—

(a) Sandifort, *Mus. Anatomicum*, Bd. ix. t. 195.

(b) Magitôt, *Ann. de Gynéc.*, 1875, Aug. and Sept. (two cases).

³ The Roman figure in each instance refers to the number of the table, and the Arabic to the case.

further pair of cases (iv., 3, 4) part of the tumour is within the cavity of the cranium, and part in the pharynx and mouth, the two portions being united by a constricted central stalk which passes through a hole in the base of the skull occupying the position of the pituitary foramen. Eight cases are included in which the attachment was to some part of the pharynx other than the base of the skull, seven which were attached in the cavity of the mouth or to the tongue, and three are included in a separate table,—two, because the site of their implantation cannot be ascertained; and one, because there were several isolated tumours in the same case. In some instances the tumour has a double attachment: I have then placed it in that group to which it belongs by what appears to have been its primary seat of implantation. In two cases the epignathus, instead of being simple, was multiple, and these two require special mention. In the first instance (v., 3) there were several small tumours on the tongue, the septum nasi, and the wall of the pharynx, which contained, amongst other elements, muscular fibres, and in one of which was discovered a milk incisor tooth. It may be argued that this is not really a case of epignathus, but I am inclined to include it amongst them, for reasons which will shortly appear. The other case is much more remarkable (iv., 6), for in it there was, in the first place, an ordinary epignathus tumour attached to the base of the skull of the autosite; and secondly, attached to this parasite by a cord—at first single, but afterwards dividing—two further *acardiaci acephali*, *i.e.* pelves, with attached lower extremities. I shall have occasion, further on, to allude more particularly to this case.

The nature of the contents varies considerably, but it is possible to arrange them in a scale commencing with the most simple, and proceeding to those in which organs and extremities are present. The most simple forms are the hair-clad pharyngeal polypi (ii., 15; iii., 5, 6, 7, 8; iv., 10; v., 3), in which the covering is cutis with hairs and glands, and the interior contains generally a rod of cartilage, connective tissue, and striped muscular tissue. From these we proceed to a group in which the tumour is much larger, often polycotyledonous, and contains pieces of cartilage, and bone, muscle, etc., but no bone or organ of recognisable character. To this group belongs the case described in this paper.

In a further group, bones of recognisable shape or teeth, or both, are present (i., 1; ii., 5, 7, 21; iii., 4; iv., 8; v., 3). Extremities, or rather, generally, the distal portions of extremities, were met with in ii., 6, 13; iv., 3, 5, 11, 14. Portions of intestine were found in i., 1; ii., 3, 6; iv., 2; and liver-cells in iv., 12. Rudimentary genitalia were described in ii., 20, and iv., 11. Brain substance or cells indistinguishable from brain-cells have been found in several cases (ii., 7, 8, 10, 11, 16; iv., 4, 13), and portions of the head or organs belonging to it in others (ii., 7, 18; iv., 3, 13).

As regards the nature of this class of monstrosity there is some diversity of opinion as to details, but I fancy that Hill (5) is quite right when he says, "most would regard it as the product of an embryo which had an existence separate from that of the embryo from which the autosite has grown in the single ovum." Or perhaps it may be put as Sutton puts it, that the condition is a "slight manifestation of a process which finds its maximum expression in some forms of duplex monsters." There are, however, some authorities who prefer to divide the cases into two groups, according to whether the tumour contains foetal organs or appendages, or not. In the former case they allow that the condition was allied to double monstrosity, but not in latter, which they call a teratoma or teratoid tumour. Such, for example, is the view of Ziegler (6), who writes: "The former tumours are undoubtedly to be viewed as remnants of parasitic foetuses which have failed altogether to develop; they are in fact *Acardiaci amorphi*, in very close relation with the well-developed twin. With regard to the latter class of tumours, this view is not so certain. It is more likely that they depend in part for their origin on some disturbance or arrest of the development of a single foetus, or on an aberration *in germine*." Förster goes further than this, for he says (7), "Unless the tumour contains some true organ, such as an extremity or intestine, it must not be looked upon as a case of *foetus in foetu*." Perls (8) is inclined to take the same view as Ziegler, but adds that all these tumours and other forms of duplicity are manifestations of the power of the germ to divide in diverse manners, and to a greater or lesser extent. Arnold (9), after considering the question of the origin of these growths

at length, suggests a new terminology, and calls those tumours which possess fœtal organs or extremities, and which must, therefore, in his opinion be referred to a second germ, 'heterochthonous teratomata.' Autochthonous teratomata, on the other hand, are to be looked upon as the development of an abnormal germ belonging to one embryo. In considering this point it is important to remember that all these statements were made before recent researches in experimental embryology had taught us many of the facts which we now know, and in the light of which I think the question may again be considered. If we consider what is meant by the phrase 'the representative of a second embryo,' we find that it is by no means so easy to define it as it was some time ago. No one would now explain the condition by postulating two originally separate ova, and few would argue that it arose from the presence of two nuclei in one ovum. According to Duval and others, a second spermatozoon entering into the ovum is the cause of double monstrosity, and such an occurrence might be postulated by this school to account for the condition in question. Whatever may be the mode of origin, however, of the second fœtus, or what we speak of in those terms, most people would, I think, admit that what is meant is, that the mass of germ-plasm out of which the major forms of epignathus at least are developed, is a mass which might, under favourable circumstances, have produced a perfect and complete individual. To what extent its development may proceed before it comes to a stop, and how far degeneration plays a part in the process, are questions which would be differently answered by different writers. That a parasite may present at one time fairly well-formed organs, which afterwards disappear by a process of retrogression, seems to be shown by an observation which d'Audeville (10) was able to make upon a fish embryo which was born with two heads of equal dimensions, and provided with all their organs complete; but, little by little, this monstrosity was effaced, the head of the right side getting the upper hand, whilst that of the left atrophied in such a manner as to be finally represented only by a little fleshy wart, on which no organs of special sense were visible. But in the case of the human parasitic fœtus, I think most persons would agree that it probably never had much normal development, but

that its progress has always been hindered and atypical. There are some difficulties which should now be considered in the way of the view that the epignathus arises from a mass of plasm potentially capable of developing into a second individual. In the first place, we are met, just as we are in the case of polydactyly and other forms of duplicity, by the fact that cases of epignathus present a perfectly unbroken series, from those of low to those of high development. It is an artificial expedient to break this series in the middle, and explain a tumour which contains shapeless masses of bone in one way, and a second tumour in which they present a resemblance to foetal bones in another. The series requires a common explanation, and that which I have mentioned seems unsatisfactory when applied to the minor cases, since there is no apparent reason why they should not have gone on to at least as advanced a condition of development as their more highly organised fellows. In cases of polydactyly, we explain the condition not by postulating the existence of the potentiality of a second foetus, but by treating it as a case of fission due to some cause or another, possibly excess of formative material, possibly original duality of determinants. Such an explanation will also, I think, suffice for cases of dignathus and diphallus, though Blanc (11) has not hesitated to postulate here the original potentiality of a second foetus. But we can scarcely invoke such an hypothesis in cases of epignathus, since the parts in excess are frequently not homologous with those to which they are attached. Secondly, in two of the cases given in the tables, the formations are multiple. In the first of these (v., 3), it is true that the tumours are small and their contents insignificant, so that it may be said that they should be removed from the category of epignathus. But if this is so, then other cases of single tumour will have to be eliminated; for if we are to exclude a tumour containing a tooth because it is not solitary, then there is no valid reason why it should be included when it is unaccompanied by other growths. Yet, if we are to accept the hypothesis of the origin of one of these tumours from a germ with the potentialities of a foetus, there seems no way out of the difficulty of considering that each of them arose from such a germ,—a theory which demands a considerable amount of strain upon the imagination. Then

there is the remarkable case of Baart de la Faille (iv., 6), in which one would have to suppose the original existence of the germs of four embryos, of which one became the autosite, one the main parasite, and the others the two acardiaci. Of course, such a theory is not incompatible with the facts. Quadruplets do occur; and in one case (12), which its author, I think rightly, believes to be unique, one of the four was a paracephalus, so that there is no inherent impossibility in three of them having taken on the condition of parasitism. But it is possible that there may be a simpler explanation.

Lastly, there is the fact that all the structures met with in the epignathus are also encountered in ovarian dermoid tumours. An example may be given in the case narrated by Repin (13), where, in a dermoid cyst, was found the rudiment of a foetus consisting of a bony mass, with three teeth, representing the head, and of a sort of body, provided with four perfectly recognisable extremities. The body was unprovided with an alimentary canal, but close beside it, in the same sac, though absolutely detached from the foetus, was a portion of intestine, as demonstrated by microscopic examination, which contained what appeared to be meconium. This is explained by Duval as a case of partial parthenogenesis; but this is only another way of stating the fact that it is the product, like other tumours of the same kind, of a mass of germ-plasm, not normally containing the potentialities of a complete foetus. This brings us to the inquiry as to what amount of germ-plasm is requisite for the development of an embryo, a question which can only be solved by further investigations in experimental embryology. It is not possible to give any *résumé* of the observations in one way or another bearing upon this point, but one or two which are specially important must here be alluded to. Wilson (14) states that "in 1891 Driesch was able to follow out the development of isolated blastomeres of sea-urchins' eggs, separated by shaking to pieces the two-cell and four-cell stages. Blastomeres thus isolated segment as if still forming part of an entire larva, and give rise to a half (or quarter) blastula. The opening soon closes, however, to form a small complete blastula, and the resulting gastrula and pluteus larva is a perfectly formed dwarf of only half (or quarter) the normal size. Incompletely separated blasto-

meres gave rise to double embryos like the Siamese twins. Shortly afterwards the writer obtained similar results in the case of *amphioxus*, but here *the isolated blastomere segments from the beginning like an entire ovum of diminished size*. The same result has since been reached by Morgan in the teleost fishes, and by Zoja in the medusæ. The last-named experimenter was able to obtain perfect embryos, not only from blastomeres of the two-cell and four-cell stages, but from eight-cell and even from sixteen-cell stages, the dwarfs in the last case being but $\frac{1}{16}$ the normal size!" So that in these cases a small fragment of the original germ-plasm is capable of producing a complete though small embryo. It has, in fact, the potentialities of a second foetus, though this is not the kind of thing which teratologists have thought of in the past when they used this expression. But the series of events described above, in which we must suppose that a qualitative division of the germ-plasm has not taken place at the period when the blastomeres have been shaken apart, does not always occur. In others this differentiation apparently takes place earlier, for Wilson again states (p. 315), "Experiments on the eggs of other animals prove that the predetermination of the cytoplasmic regions may be more extensive. In the egg of the ctenophore, for example, Driesch and Morgan, confirming the earlier observations of Chun, proved that an isolated blastomere of the two- or four-cell stage gives rise not to a whole dwarf body, but to a half- or quarter-body, as Roux had observed in the frog. But, more than this, these experimenters made the interesting discovery that if a part of the cytoplasm of an *unsegmented* ctenophore-egg were removed, the remainder gave rise to an *incomplete larva, showing certain defects which represent the portions removed*. Again, Crampton found that in the case of the marine gasteropod *Ilyanassa*, isolated blastomeres of two-cell or four-cell stages segmented exactly as if forming part of an entire embryo, and gave rise to *fragments* of a larva, not to complete dwarfs, as in the echinoderm."

From these facts we learn that, in certain forms at least, small fragments of germ-plasm may develop into an embryo or part of an embryo, a process which is evidently what occurs in the ovarian dermoid from an ovum, and, it may be added, in the case of certain dermoids of the testis, apparently also from a

spermatozoon. Does not this make it conceivable, or even probable, that the epignathus is not necessarily the representative of a second embryo, as it has been so often called, nor even the derivative of a mass of germ-plasm which at any time possessed the potentialities of developing into a second embryo? On the contrary, is it not probable, from the facts brought forward, that it has its origin in a small fragment of germ-plasm with limited possibilities, perhaps segmented off from the ovum, perhaps derived from some other source, possibly even from a spermatozoon or polar body? The place of its origin must be left an open question, to be solved some day by further experimental researches; but the theory which I desire to suggest is, that it is not the equivalent of a germ-plasm of full embryo-producing power, but that it possesses varying and more limited potentialities of development. How does such a fragment of germ-plasm come to take up its position within the mouth or pharynx? Ahlfeld's theory, that the second smaller foetus is drawn into the stomodæum of the larger, is well known, and has been criticised by Hill. The view which is put forward in this paper is not open to Hill's most powerful objection, that there would have to be a most extraordinary disparity existing between the two embryos at the early period at which the stomodæum is formed, for one to pass into that cavity in the other, without producing much greater disturbance in the development of that part of the autosite than is usually the case. Whatever is drawn in, I submit that it must pass in with the oral invagination of the epiblast, for in no other way is it easy to account for the diversity of site exhibited by these tumours. All the positions which they have been seen to occupy, including that of a partly extra- and partly intra-cranial situation, can be explained by this means. It would certainly be easier to understand how a small portion of detached developing germ-plasm might be carried in to the stomodæum in this manner, than how an embryo of the same age, though smaller than that of the autosite, should take such a track.

Recent observations by Schaper (15) throw an interesting light upon the possibilities of development of the epignathus after its final implantation within the oral cavity. With a very sharp knife, he cut off all that part of the head in very young tadpoles which contains the brain and medulla oblongata. Many

of the tadpoles died, but others lived, and continued swimming about and developing for some time, showing that "the absence of the central nervous system was practically of no demonstrable importance whatever in the differentiation of the embryo, at least during the period of our experiment." In another case, all the brain and organs of special sense were cut away save the anlage of one eye, which, however, went on developing, so that at the end of the experiment it was but little less advanced than that of an untouched embryo of the same age. Dr Schaper thinks that these facts prove that, as Roux has suggested, the earlier period of development of an embryo is one of organo-genetic development, during which "the different organs develop by means of an inherent endogenous energy in a definite direction without influence from outer stimuli, that is, by auto-differentiation." Further, he thinks that in this power of auto-differentiation we have the key to the power of developing important organs possessed by teratomata, and, it may be added, tumours of the class with which this paper deals.

TABLE I.

Tumour with attachment to tongue or mouth, but not palate.

No.	AUTHOR.	IMPLANTATION.	CONTENTS (e).
1.	Vrolik.	Left cheek.	Intestine, tibia, astragalus, calcaneum, and other bones.
2.	Studencki (1).	Tongue and lower jaw.	Fragments of bone and cartilage.
3.	Gilles.	Left cheek.	An incisor, also a bone, like inf. maxilla with teeth.
4.	Baldy.	Upper surface of tongue.	Not specified.
5.	Verneuil.	Between lower jaw and tongue.	Hyaline cartilage and bone.
6.	Otto (354).	Upper lips.	"Totus tumor e tela cellulosa constipata constat."
7.	Otto (355).	Do.	Do.

(e) Only the most important structures have been mentioned in each case.

TABLE II.

Tumour with attachment to palate or superior maxilla.

No.	AUTHOR.	IMPLANTATION.	CONTENTS (e).
1.	Studencki (2).	Palate.	Bones of unrecognisable shape.
2.	Otto (587).	Rt. sup. max. and nose.	Bones and cartilage.
3.	Otto (588).	Palate and left cheek.	Intestine and testicle (?).
4.	Retzius.	From cleft in palate.	Bones.
5.	Hess.	Sup. max.	Bones, two of which bore teeth.
6.	Kidd.	Hard palate.	Cartilage, fingers, toes, intestine.
7.	Wegelin.	Palate, but part projected into cranium through pituitary for.	Sacrum, crystalline lens, fragments of brain, intestine.
8.	Hecker.	Rt. sup. max.	Cartilage and embryonic brain-cells.
9.	Neuffer.	Hard palate.	Nothing special.
10.	Ahlfield.	Do., and back of pharynx.	Cartilage, bone, foetal brain-substance.
11.	Löwi.	Palate, upper and lower jaws.	Cartilage and brain-cells.
12.	Davis.	Sup. max.	
13.	Stockwell.	Sup. max. (?).	Thumb and two fingers, foot.
14.	Broca.	Palate to lower jaw.	
15.	Muzio.	Hard palate.	Hair - clad polyp, muscle, no cartilage.
16.	Muller.	Do., nose, pharynx.	Cartilage and brain-cells.
17.	Mauché.	Hard and soft palates.	Cartilage and splinter of bone.
18.	R. C. S. Eng.	Sup. max. and lips.	Mouth and single nostril, 59 bones.
19.	Clerault.	Palate.	Striped muscle.
20.	Otto.	Hard palate.	Penis and scrotum, bones, nerves.
21.	Hen.	Palate.	Cartilage, bones, one with dental sacs.
22.	Sangalli.	Hard palate.	Plates of bone and striped muscle.

TABLE III.

Tumour with attachment to pharynx, not including upper part.

No.	AUTHOR.	IMPLANTATION.	CONTENTS (e).
1.	Breschet (1).	Pharynx.	Debris of small fœtus.
2.	Breschet (2).	Do.	Do.
3.	Otto (586).	Do.	Nothing special.
4.	Poelmann.	Outer side of Eustachian tube.	Bone, cartilage, 22 teeth.
5.	Arnold.	Back of left half of velum palate.	Hair-clad polyp, with striped muscle.
6.	Otto.	Back of soft palate.	Hyaline cartilage, nerve fibres.
7.	White.	Soft palate behind uvula.	Cartilage and glands.
8.	Schuchardt.	Post. wall pharynx.	Hair-clad polyp, without cartilage.

TABLE IV.

Tumour attached to the basis cranii.

No.	AUTHOR.	IMPLANTATION.	CONTENTS (e).
1.	Haack.	? basis, hung through an opening in hard palate.	Bones like vertebrae and ? two feet.
2.	Sönmerring.	Base of skull.	Lower extremities and intestine.
3.	Rippmann.	Two tumours, connected by stalk through sella turcica.	Outer tumour, a bone like lower jaw; inner, extremities, with fingers and toes.
4.	Arnold.	Much as above.	Hyaline cartilage, striped muscle and brain-like substance.
5.	B. de la Faille.	Stalk of tumour passes through pituitary foramen.	Bones, rudiments of extremities, with fingers and toes.
6.	Do.	As above.	To the tumour are attached two acardiacephali.
7.	Sonnenburg.	Base of skull.	A bone, also an eyelid.
8.	Windle.	Basi-sphenoid and floor of mouth, splitting tongue, in a calf.	Bones and teeth.
9.	Windle.	Tubular stalk through pituitary foramen.	Many fragments of bone and cartilage.
10.	Abraham.	Basis cranii.	Hair-clad polyp, with cartilage.
11.	Kreutzmann.	Vomer and basis cranii.	Two lower extremities and imperfect female genitalia.
12.	Hill.	Basi-sphenoid and back of vomer.	Embryonic liver.
13.	Guillebeau.	Basi-sphenoid (calf).	Rudimentary head, without lower jaw, contained brain.
14.	Wasserthal.	Stalk passed through pituitary foramen.	Lower extremity and other fetal remains.

TABLE V.

Miscellaneous.

No.	AUTHOR.	IMPLANTATION.	CONTENTS (c).
1.	Adelmann.	? pharynx, associated with cleft palate.	
2.	Lambl.	Not accurately described.	Hair-clad sebaceous glands, no cartilage.
3.	Wallmann.	Several tumours on tongue and septum nasi, and in pharynx.	Muscle fibres and a milk incisor.

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ON THE RANGE OF APPLICABILITY OF CERTAIN MODIFICATIONS OF THE WEIGERT-PAL PROCESS.

By JOSEPH SHAW BOLTON, B.Sc., M.D., B.S. (Lond.), *Demonstrator of Physiology in Mason University College, Birmingham.* (PLATES V.-IX.).

SINCE the publication of my paper¹ on the nature of the Weigert-Pal method when applied to formalin-hardened human cortex cerebri, I have made extensive use of the methods of procedure there recommended, and have amply verified my results and conclusions. I have also applied these methods to numerous regions of the vertebrate nervous system with equally satisfactory results. I consequently desire to draw attention to these results, and also to make certain suggestions with reference to the relative value of the methods in different cases, and to the technique of the process under different circumstances.

I do not propose, as in my previous paper, to give a detailed account of the very numerous differentiations I have performed, both from considerations of space, and also because this is rendered unnecessary owing to the micro-photographs with which this communication is illustrated. In the preparation of these micro-photographs I have received the invaluable assistance of Professor F. J. Allen, who has not only placed his very complete micro-photographic apparatus at my disposal, but has also given me the benefit of his ripe experience in photography.

All the specimens referred to in this paper have been hardened in 5 per cent. formalin and cut, without previous soaking in gum, by the freezing method, the sections being preserved until required for use in 5 per cent. formalin. They were prepared by one or other of the osmic acid, iron alum, and ammonium molybdate methods which I recommended and detailed in my earlier paper. The duration of the different stages of the process varied, of course, according to the special characteristics and requirements of the several sets of sections prepared. As such necessary modifications are quite readily determined by experiment in any particular case, they will not be further

¹ *Journal of Anatomy and Physiology*, xxxii. pp. 247-266.

referred to here ; for, in view of the great diversity in the size, thickness, density, and complexity of the sections which pass under treatment, experience and correct judgment are necessary in order to obtain the best results.

I have selected the following examples, either because they are typical of the results which can readily be obtained by the use of the given method, or because they demonstrate some point of interest, either as regards possible histological structure, or with reference to the elucidation of the nature of the staining process.

Human cortex cerebri.—Plate V. figs. 1 and 2.—The appearances seen in the human cortex cerebri in fully differentiated specimens require little reference here, as they are described at length in my previous paper. According to the mordant used, and to the degree of differentiation effected, the axis-cylinders alone may be stained, the medullary varicosities appearing as transparent, colourless swellings ; or the varicosities may also be stained to any degree, and even so deeply that no difference in intensity is visible, both axis-cylinder and medullary substance being, in some iron alum specimens for example, jet-black.

Plate V. fig. 1 shows the appearance of the cortex of the calcarine fissure in a finely differentiated specimen prepared by the osmic-acid-chrome-alum method. The dark line in the right half of the illustration is the line of Gennari. As the photograph has been prepared for another purpose, further description here is unnecessary.

Plate V. fig. 2 shows the surface part of a portion of this section more highly magnified, and with a lens the structure of the numerous fine medullated, varicose, and non-medullated fibrils can be fairly well made out. This is, however, owing to their minute size, only clearly visible in a good lantern-plate examined in a bright, diffused light, with a lens.

Medulla oblongata and spinal cord of Cat.—Plate VI. gives examples of the results I have obtained in other parts of the mammalian central nervous system. Fig. 1 is taken from a photograph of the nucleus of origin of the hypoglossal nerve of the cat, prepared by the ammonium molybdate method. Whilst it is a successful photograph, it is, however, very inferior to the actual specimen, though, when examined with a lens, it is a good test of the excellence of the method, and of the distinctness of

the fibrils displayed. Owing to the ease with which this particular type of section can be prepared, to the cheapness of the materials, and to the beautiful results which are obtained, the method is a very suitable and useful one for class purposes. The sections, however, require to be examined by daylight, as the appearance by artificial light is very disappointing unless the light used be white.

Fig. 2 is prepared from a section of the spinal cord of the cat in the region of the anterior ground fibres, prepared by the osmic acid method. It is best examined with a lens. It shows well the appearances usually found in thin, properly differentiated specimens containing mixed fibres. Whilst in thicker sections in the region of the crossed pyramidal tract, rings, consisting of the deeply stained outer parts of the medullary sheath, are almost alone visible, here in nearly every cross-section of a fibre the axis-cylinder may be seen lying, deeply stained, either in the centre, or more usually to one side of the clear space inside each ring. In some cases the outer and inner parts only of the medullary sheath are stained, the intermediate portion being clear. Though a photograph, however good, is much inferior to the actual specimen, these points are sufficiently evident in the illustration, and amply verify the conclusions at which I arrived as the result of a minute examination of the fibrils of the cerebral cortex.

Peripheral nervous system.—Plate VII. fig. 1 is from a photograph of a longitudinal section of a posterior root ganglion of the cat, prepared by the ammonium molybdate method. Osmic acid duplicates exhibit identical appearances. The staining of the medullary sheath is interesting. The regularly varicose appearance of the stained axis-cylinder and sheath, and particularly the fact that the varicosities appear, as it were, to be cones all lying in one direction, suggest that the medullary segments or cones of Lantermann may really be structural features of the medullated fibre. The fact that the varicosities keep their stain longer than the rest of the medullary sheath suggests that they are highly protoplasmic in nature. The remainder of the sheath is therefore presumably highly fatty in structure, and hence traumatic rupture would be more likely to occasionally occur here, and thus to form in places the usual

medullary segments. That osmic acid specimens can be obtained presenting the same appearances, is of course due to excessive differentiation washing away the outer and consequently exposed part of the medullary sheath. Fig. 2, which is from a photograph of a moderately mordanted ammonium molybdate section of the sciatic nerve of the dog, shows similar appearances in its different trans-sections of nerve fibres. In some of the cross-sections the whole medullary sheath is deeply stained, the axis-cylinder showing only faintly. In others the axis-cylinder is the most deeply stained part, and lies loosely inside the ring of medullary sheath. In others, again, the medullary sheath is deeply stained in parts of its circumference only, this occurring either as six sections, separated by gaps, or as six dots, surrounding the axis-cylinder, the outer part of the sheath being practically unstained; or finally, as some appearance intermediate between these two. These different stainings of the several fibres are readily explicable if they be looked upon as the appearances of cross-sections made in various positions along the course of the fibres shown in fig. 1, naturally altered in many ways owing to cross-section differentiation. Without attempting to draw a sweeping deduction from these appearances, I have thought it desirable to notice them here, as they are certainly not without interest with reference to the elucidation of the intimate structure of the medullary sheath of nerve fibres. It would be surprising, to say the least, were such a mathematically exact staining, which is almost in some respects analogous to the staining of the spongioplasm of a muscle fibre, due solely to an accidental shrinking or precipitation of the neuro-keratin of the medullary sheath.

Central nervous system of the Frog.—Plate VIII. (figs. 1 and 2) shows the appearance of iron alum specimens of the medulla oblongata of the frog under low and high powers respectively. The detail from a general point of view is fairly well shown in fig. 1, but is too minute for a photograph to do full justice to it.

Fig. 2 illustrates, magnified to 157 diameters, the nerve nucleus at the left extremity of fig. 1. Both nerve cells and nerve fibres are beautifully shown, their relative size being made clear by the accidental inclusion of a group of blood corpuscles which is visible at the right side of the photograph.

Central nervous system of the Minnow.—Plate IX. (figs. 1 and 2) is prepared from photographs of the medulla oblongata of an adult female minnow. Fig. 1 is magnified 38 diameters, and the actual specimen is consequently only about one-seventeenth of an inch in diameter. The section was prepared by the ammonium molybdate method.

Fig. 2 is taken from an iron alum preparation of another similar section, magnified 205 diameters, and showing the grey matter of the dorso-lateral region. A comparison with the less magnified Plate VIII. fig. 2 of the frog will demonstrate the extreme minuteness of the network of nervous fibrils in the medulla oblongata of the minnow. Such exceedingly minute sections, containing, as they do, both very coarse fibres, and quite near these, small meshworks of very fine and also very short fibrils, require, for their satisfactory preparation, staining, and mounting, when conducted, as is my custom, without the use of adhesive methods, no inconsiderable amount of practice.

The failure of Herrick—whose paper¹ contains a lengthy criticism of my previous publication—to obtain successful results with the brains of minnows, not only by my own but by several other methods, is in all probability due to some difference in technique. Herrick states that my methods “were repeated in several cases as exactly as possible, but with quite dissimilar results.”² He, however, used 10 per cent. formalin instead of 5 per cent., and also sectioned the brain in paraffin, instead of by simply freezing from formalin. For the successful application of any method to different parts of the nervous system, and to the nervous system of different animals, an intelligent modification of the general directions given, until success is obtained, is of course necessary. If, however, such a radical change as sectioning in paraffin instead of by freezing is made in a method, a difference in results is to be expected, and this is probably the explanation of Herrick’s failures. My illustrations are a sufficient reply to his statement: “It is an interesting fact that those methods, which in Bolton’s hands gave the best results upon the human brain, failed utterly when applied to fish brains.”³

¹ *The States Hospitals Bulletin*, vol. ii. No. 4, pp. 431-461.

² *Loc. cit.*, p. 453.

³ *Loc. cit.*, p. 455.

RELATIVE VALUE OF METHODS.

The Osmic Acid Method.—For ordinary relatively coarse nervous tissue, *e.g.*, in the greater part of the human nervous system, the osmic acid method is invaluable, owing to the very rapid action of the osmic acid on the medullary sheath, and also to the jet-black character of the lake which is formed. With sections containing very fine fibrils, however, especially if they are short and form complex meshworks, as in the minnow, and particularly when they are non-medullated, it gives inferior results to those obtained by the use of iron alum or ammonium molybdate. Plate VI. fig. 2 is from a photograph of a section prepared by this method. The axis-cylinders can readily be detected inside the dark rings formed by the sheaths. The use of a chrome compound is, as I stated in my previous paper, quite unnecessary. Plate V. figs. 1 and 2 are prepared from sections of human cerebral cortex, mordanted with osmic acid and chrome alum.

The Iron Alum Method.—Iron alum is in my hands, in many respects, a most satisfactory mordant. The lake formed is relatively insoluble. The axis-cylinders and medullary sheaths, if present, are deeply stained, and particularly if, as in the brains of small fishes, the fibrils are very minute, it gives excellent results. More frequently, however, than in the case of the other methods, owing to the relatively insoluble nature of the lake, nodes exist in the fibrillar meshwork, and it is not unusual to find the nerve cells beautifully stained. Examples of iron alum specimens have been employed for the preparation of Plate VIII. figs. 1 and 2, and of Plate IX. fig. 2. The sections prepared by this method require careful washing between the iron alum and the logwood baths. The iron alum solution should also be freshly prepared, and should not be used a second time.

The Ammonium Molybdate Method.—Ammonium molybdate for most general purposes is a very satisfactory mordant. The colour is very agreeable; and with a yellow screen, the sections photograph readily. In the case, however, of very minute fibrils, iron alum gives better results, owing to the then relatively faint

colour of the molybdate lake. I have already stated that, for ordinary tissues such as the medulla oblongata and spinal cord, the molybdate method is very suitable for general class purposes, owing to the cheapness of the materials, and to the ease with which beautiful effects can be obtained. The mordant bath can be used again and again, differentiation is very rapid, and with ordinary care the specimens do not readily spoil. They require, however, to be passed as rapidly as possible through alcohol when mounting. Thorough washing after differentiation and perfectly pure neutral or faintly alkaline absolute alcohol minimise the danger of failure. Plate VI. fig. 1, Plate VII. figs. 1 and 2, and Plate IX. fig. 1 are prepared from examples of this method.

Comparison of Methods.—Osmic acid, being a much weaker mordant than ammonium molybdate or iron alum, and having a special affinity for medullary tissue, is consequently in many respects the best substance to use when the sections contain ordinary coarse nervous tissue. With the use of a moderate amount of care, also, it is the least likely of the three to stain bare axis-cylinders and collaterals. Iron alum, on the other hand, is by far the strongest mordant of the three; and the whole nervous meshwork, to its minutest ramifications, and including the nerve cells, remains stained after all the binding tissue has been decolorised. Ammonium molybdate occupies an intermediate position, and is consequently most useful for tissues containing neither very large nor very small fibres.

GENERAL CONSIDERATIONS.

The chief conclusion drawn from the results of my previous investigation, that "the Weigert-Pal process is not a specific method for the staining of medullated fibres with hæmatoxylin, but is a method of dyeing fibrils which comprises three distinct operations—the mordanting of the fibrils, the formation of a lake in them, and finally the removal of the stain by oxidation from nearly every other part of the complex tissue under treatment," which primarily applied to the human cortex cerebri only, can consequently be reaffirmed as regards the entire nervous system. If it be borne in mind that only those portions of the sections which possess a high degree of metabolic

activity absorb the mordant and fix the lake which is formed in their substance, the various appearances in the specimens from which the illustrations have been prepared can readily be explained. The minute nervous meshworks in the minnow, composed of short tangled fibrils, and lying in the immediate neighbourhood of much coarser fibres, require complete mordanting and slow differentiation, with many alternate baths, to bring them out clearly, as otherwise they decolorise without any differentiation whatever. The relatively coarse fibres in longitudinal sections of nerve or ganglion, on the other hand, very readily differentiate, the nerve cells, when present, decolorising more rapidly, owing to the absence in their case of such a protection from the oxidising agent as is provided by the bundling together of the fibres, and the presence around them of binding tissue; and also because the nerve cells are usually cut across, either on the one surface of the section or on the other. If, however, the section of nerve or ganglion be transverse, the results of differentiation vary according to circumstances. In the case of large well-mordanted fibres, the axis-cylinder washes out before the medullary sheath, leaving a ring; whereas, if the same fibres be less strongly mordanted, a differentiation of the cross-section takes place, exhibiting the appearances shown in Plate VII. fig 2. Small fibres, again, to appear at all in transverse section, must be well mordanted; and in these, as shown in Plate VI. fig. 2, both the axis-cylinder and the medullary sheath are stained, the former being usually the first to decolorise, though it can generally be seen lying flattened out against one side of the inner circumference of the dark ring of medullary sheath. If, however, the small fibres lie chiefly longitudinally, as in cross-sections of the mammalian medulla oblongata, etc., they differentiate quite readily, and give excellent results, the axis-cylinder being in most cases stained throughout its course, and the medullary sheath being stained faintly or intensely, according to the mordant employed.

CONCLUSIONS.

1. *Range of Applicability of Methods.*—Reference to the illustrations shows that the methods described in a previous paper

are applicable not only to the human cerebral cortex, but also to the bulb, cord, peripheral nerves, and ganglia of mammals, and to the nervous system of the frog and fish.

2. *Nature of the Weigert-Pal Method.*—The present more extended investigation has confirmed the conclusions which were arrived at from a study of the human cerebral cortex concerning the nature of the Weigert-Pal method, and these conclusions require neither addition nor modification in their wider application.

EXPLANATION OF PLATES V.-IX.

PLATE V.

Fig. 1. Human cortex cerebri in the region of the calcarine fissure. 26 diameters. Osmic acid and chrome alum.

Fig. 2. Ditto at surface of cortex. 141 diameters. Osmic acid and chrome alum.

PLATE VI.

Fig. 1. Nucleus of origin of xii nerve of cat. 58 diameters. Ammonium molybdate.

Fig. 2. Anterior ground fibres of spinal cord of cat. 163 diameters. Osmic acid.

PLATE VII.

Fig. 1. Longitudinal section of posterior root ganglion of cat. 32 diameters. Ammonium molybdate.

Fig. 2. Transverse section of sciatic nerve of dog. 218 diameters. Ammonium molybdate.

PLATE VIII.

Fig. 1. Medulla oblongata of frog. 37 diameters. Iron alum.

Fig. 2. Lateral portion of ditto. 157 diameters. Iron alum.

PLATE IX.

Fig. 1. Medulla oblongata of minnow. 38 diameters. Ammonium molybdate.

Fig. 2. Dorso-lateral portion of ditto. 205 diameters. Iron alum.



FIG. 1.—26 Diameters.



FIG. 2.—141 Diameters.

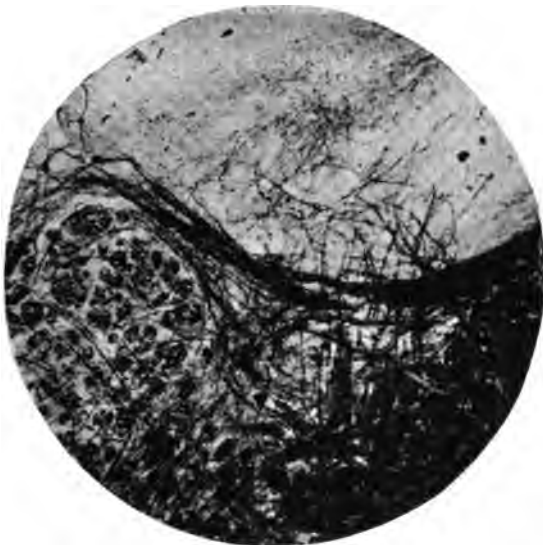


FIG. 1.—58 Diameters.



FIG. 2.—168 Diameters.





FIG. 1 —32 Diameters.

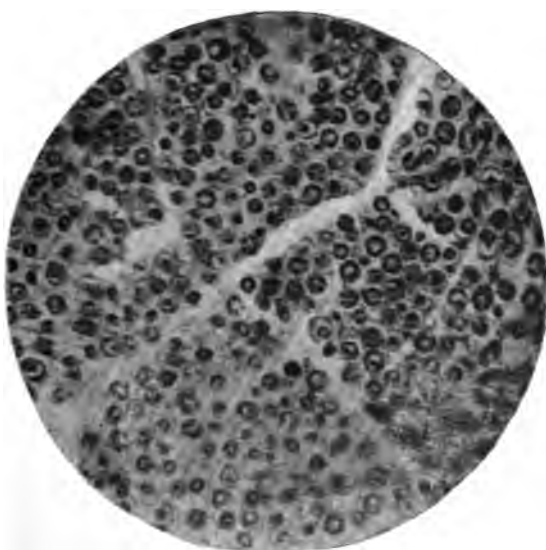
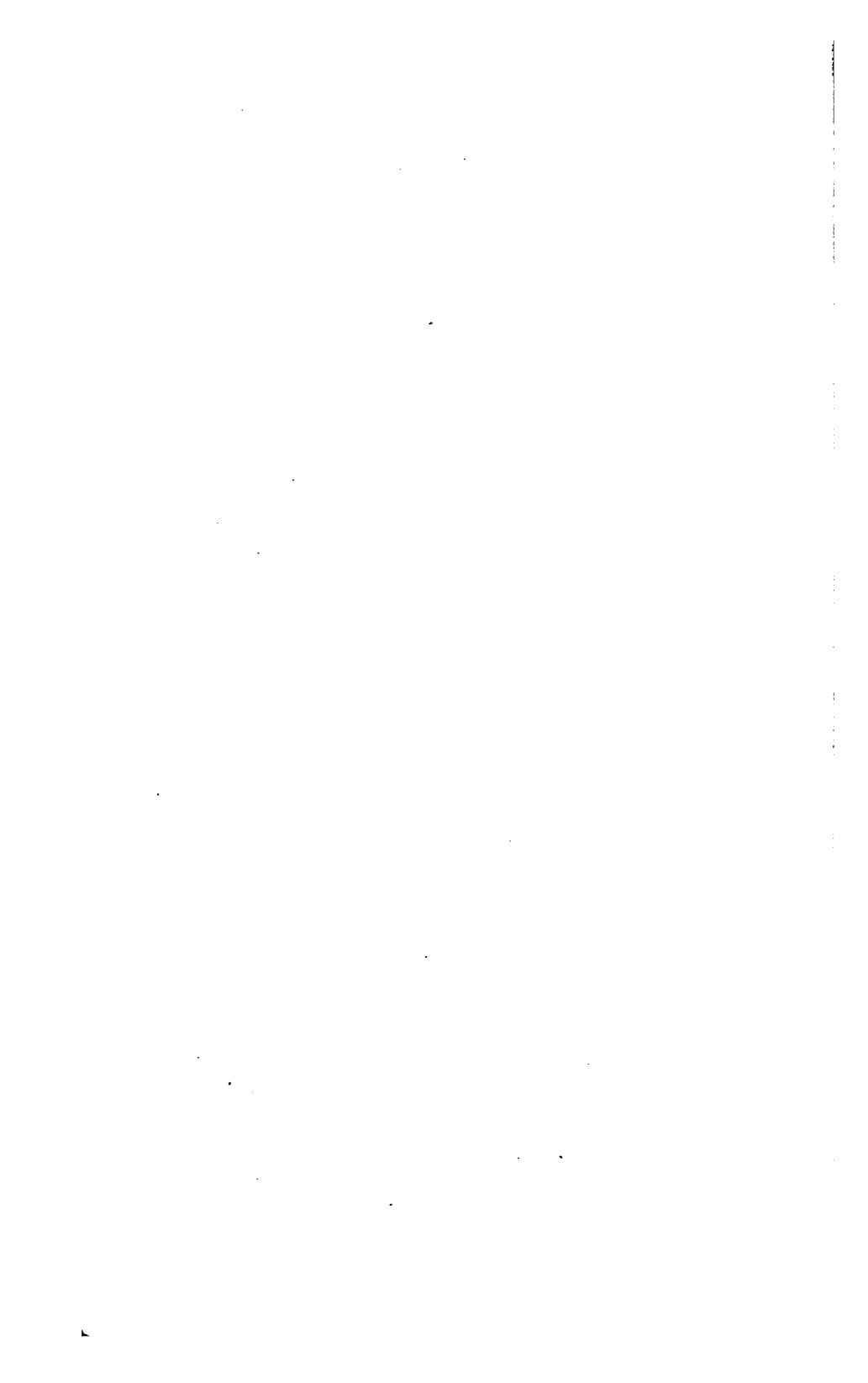


FIG. 2.—218 Diameters.



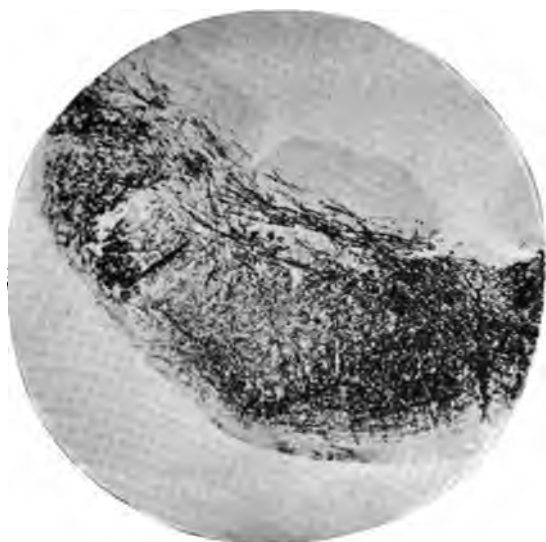


FIG. 1.—37 Diameters.



FIG. 2.—157 Diameters.

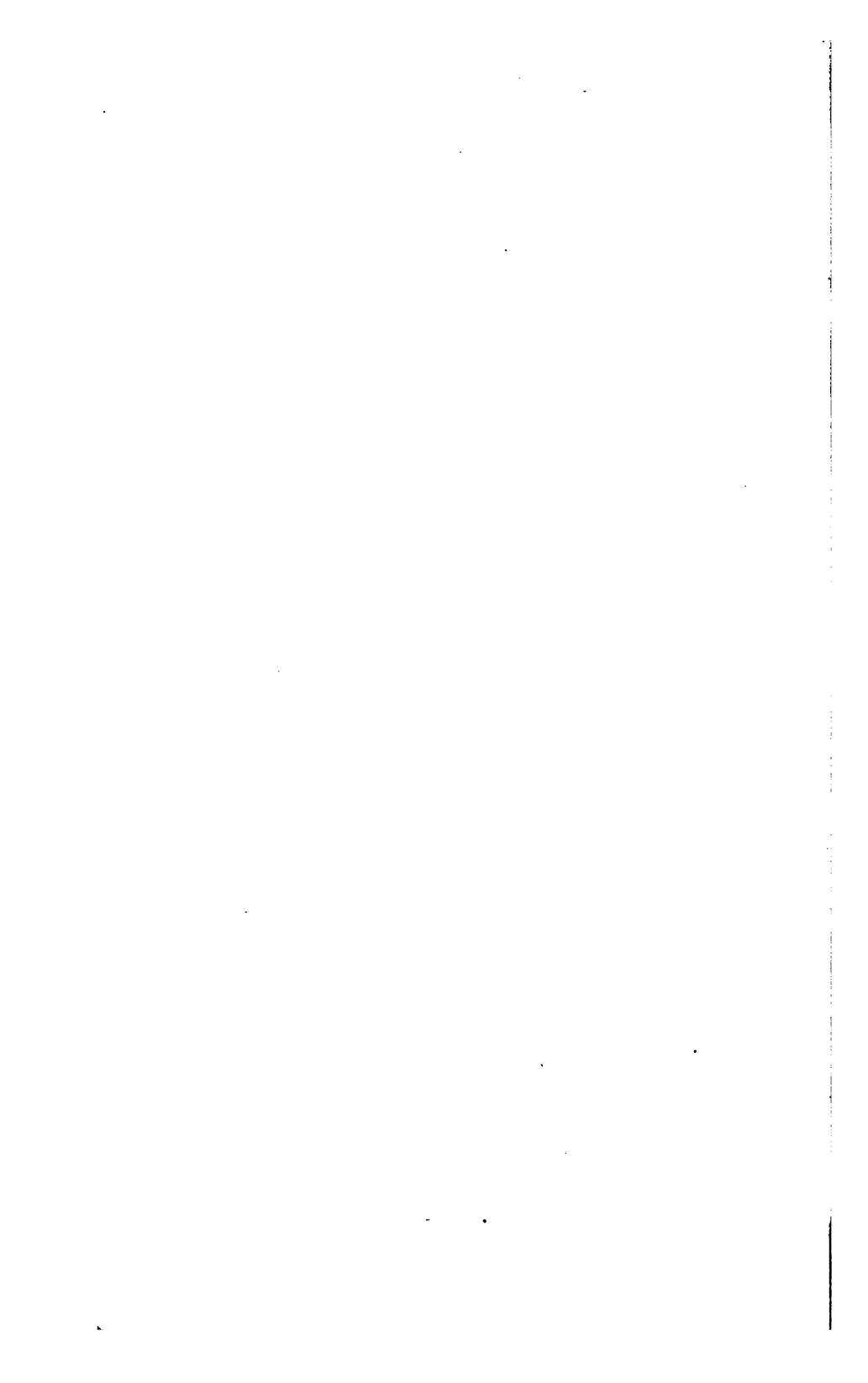
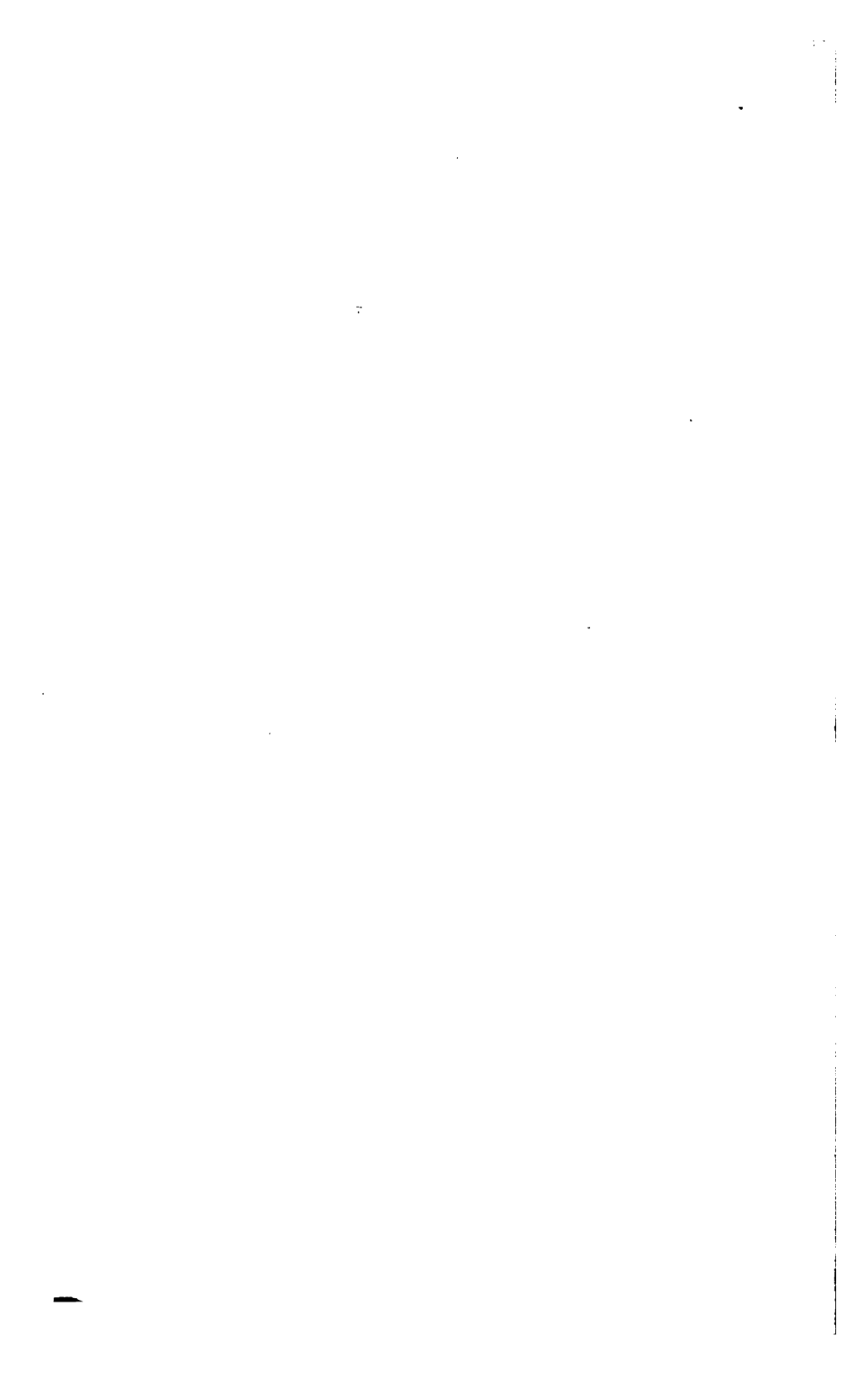




FIG. 1.—38 Diameters.



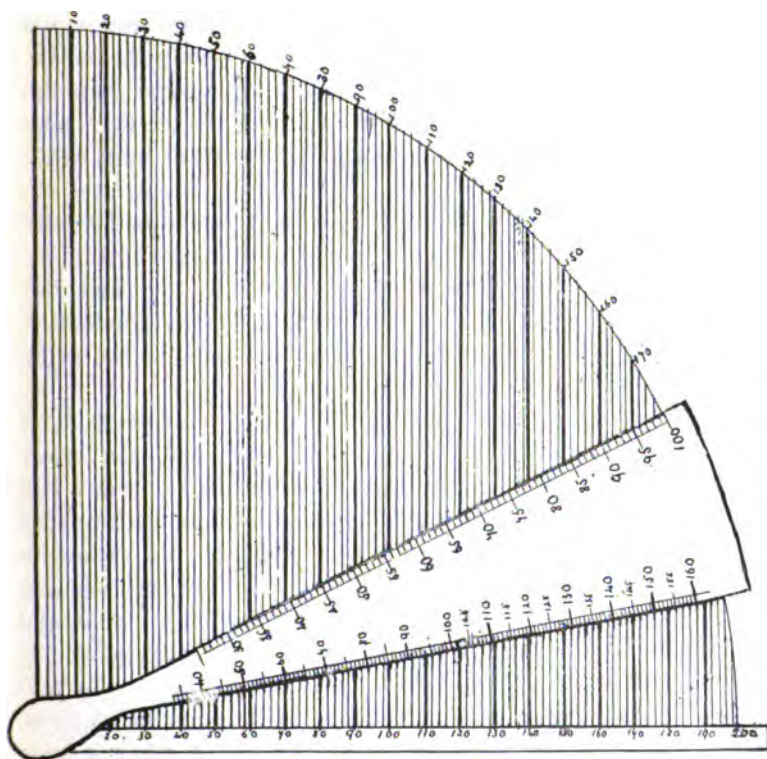
FIG. 2.—205 Diameters.



AN OSTEO-METRIC INDEX CALCULATOR. By DAVID WATERSTON, M.B., F.R.C.S.E., *Demonstrator of Anatomy, Edin. Univ.*

THE accompanying illustration shows a simple instrument by which indices required in osteometric observations can be determined without the loss of time and the possible inaccuracy attending an arithmetical calculation.

The instrument I have constructed consists of two parts. One



is a plate 250 mills. square, engraved with a graduated quadrant, and the other is a movable arm, also graduated, and fixed to the plate. The radius of the quadrant is 200 mills. in length, this number being chosen for convenience, as the majority of

skulls do not exceed this figure in their greatest measurements. The radius at the lower part of the plate is divided at every two mills., and from each point a vertical line is drawn to meet the circumference. The points of division are numbered off from the centre, and for convenience the figures are repeated where the lines meet the circle.

The movable arm is in the shape of a segment of the circle, and is pivoted at the centre of the circle. The edges of the arm are graduated as follows:—The upper edge is divided into 100 equal parts, numbered at every five. The lower edge, used for the smaller cranial measurements, has a point at 120 millimetres distance from the centre, marked as 100, and this distance of 120 millimetres is divided into 100 equal parts, and the same subdivision is continued along the edge.

The distance of 120 was chosen as being greater than the largest measurement met with in determining the gnathic index in man. The method of using the instrument will most easily be explained by an example:—

To find the cephalic index from two figures, such as 178 and 126, move the arm till its upper edge is at the point 178 in the circumference; then follow down the line from the point 126 on the circumference till it meets the arm, and the graduation nearest the point where the line meets the border is the index required, which can be read off at once.

Should an index be required from smaller measurements, or from measurements giving an index of over 100, the lower border of the arm is used. Move the arm till the point 100 on the lower edge rests on the line which leads from the first figure—the measurement which would be the divisor in doing the calculation arithmetically—and follow up the line from the second measurement till it meets the lower border, and again read off the index from the graduation at that point. If the figures be 'odd,' the eye can measure accurately the mid point between two lines, which, of course, is the point required. This appliance will be found especially useful when a large number of indices have to be calculated out from a series of figures, and also in checking results which have been arithmetically obtained; and instruments on the same principle can be made for giving indices for the pelvis, femur, etc.

The only apparatus of the kind of which I have been able to find any record is a 'scale' figured and described by Mr G. M. Atkinson in the *Journal of the Anthropological Institute* for 1879, and his instrument has several disadvantages from which mine is free.

His scale contains different divisions for different indices, and as some of the scales are very small, the subdivisions are very minute, and therefore difficult to read; and the multiplicity of figures is rather confusing. To use his scale, one needs to mark off the measurements with a pair of compasses, which is also inconvenient.

I have to thank Sir W. Turner for his valuable suggestions in working out a final form for this appliance, which, I venture to hope, will lighten the labour of those who have to go through the troublesome and tedious work of repeated arithmetical divisions.

Arrangements are being made with Mr Casella, of Holborn Bars, London, by which he will be able to supply the instrument at a moderate price.

NOTE ON THE OVARIAN OVA OF THE HEDGEHOG.¹

By E. WACE CARLIER, M.D., *Lecturer on Experimental Physiology and Histology in the University of Edinburgh.*

THE ovary of the hedgehog appears to contain at all times abundance of Graafian follicles in various stages of development, and owing to its compactness is a very suitable object for the study of the changes taking place in the ova during growth and early maturation. The nucleoli of the ova are very prominent, and it is to them chiefly that I wish to direct attention in this communication.

Even in the earliest stages, when the Graafian follicle is represented by a single layer of flattened cells arranged around the ovum, the nucleolus of the latter is of considerable size, measuring some $2\ \mu$ in diameter. It is central in position, homogeneous in appearance, staining deeply with appropriate dyes, and apparently quite solid. The nucleus at this stage measures $10\ \mu$ and the protoplasm $20\ \mu$ in diameter.

With the growth of the ovum the nucleolus increases steadily in size; by the time the follicle cells, which form a single layer, have become cubical in shape, the diameter of the nucleolus of the ovum has reached $4\ \mu$, *i.e.*, it has become doubled, whilst the nucleus measures $16\ \mu$ and the protoplasm $27\ \mu$.

At a somewhat later stage, when the single row of follicle cells has become replaced by several rows, the nucleus of the ovum is seen to be surrounded by so-called "yolk nuclei," which lie in the protoplasm quite close to the nuclear membrane. The egg has now grown to a considerable size, namely, $38\ \mu$ in diameter; its nucleus, which still occupies a central position, measures $22\ \mu$, and the solid nucleolus $5\ \mu$ in diameter.

By the time the rounded "yolk nuclei" have migrated half way through the protoplasm, the nucleolus measures $6\ \mu$ in diameter; it still appears homogeneous, though somewhat paler in colour at its centre. The nucleus now measures $28\ \mu$ and the protoplasm $51\ \mu$ in diameter.

When the "yolk nuclei" have almost reached the periphery

¹ Read before the Scottish Microscopical Society, January 14, 1898.

of the yolk, and have spread themselves out into a layer of flattened bodies round its margin, a change is visible in the nucleus; it is no longer rounded in shape, but irregular in outline, indicating that it is undergoing amoeboid movements, as observed by Balfour in *Asterias*;¹ it no longer lies quite in the centre of the egg, having begun its journey towards the zona pellucida. The nucleus now measures $26\ \mu$ in diameter, and seems to have attained its maximum size. The egg measures $53\ \mu$ across. A change has occurred also in the nucleolus, at least one distinct vacuole has made its appearance in its centre; this vacuole is probably filled with a fluid that contains no stainable material. The nucleolus now measures $7\ \mu$ in diameter.

It sometimes happens that at about this period the nucleolus is bodily extruded from the nucleus into the protoplasm, where it apparently breaks down and disappears, but more often it is retained within the nucleus and undergoes further vacuolation.

At a still later date, when the liquor folliculi is just making its appearance, and the 'yolk granules' are much wasted and closely applied to the zona pellucida, and the nucleus by its amoeboid movements has passed from the centre close to one side of the ovum, the nucleolus, which now measures $8\ \mu$ in diameter, presents a number of vacuoles,—a large one, some $5\ \mu$ in diameter, occupying its centre, surrounded by many smaller ones; or there may be present in it many vacuoles of different sizes, without any special arrangement. The egg measures $58\ \mu$ in diameter, but the nucleus remains of the same size as before, measuring only $26\ \mu$.

This vacuolation of the nucleolus was noticed by O. Hertwig² in the ova of *Asterias*, by Häcker³ in those of starfish and of echinoderms, and by many others.

Häcker describes one central and several peripheral vacuoles. These in the living ova exhibited rhythmical periodicity lasting four to eight hours. He maintains that during diastole of the central vacuole, the peripheral ones diminish in number and size, and that during systole of the central one they increase.

¹ F. M. Balfour, *Quart. Micr. Jour.*, 1878, p. 116.

² O. Hertwig, "Weitere Beiträge," etc., *Morphologische Jahrbuch*, Bd. iii. Heft iii.

³ Häcker, see *Leçons sur la cellule*, Henneguy, Paris, 1896, p. 105.

He believes that the nucleolus plays an important part in nutrition of itself, of the nucleus, and of the cell.

In still larger ova, measuring $63\ \mu$ in diameter, the nucleus again measures $26\ \mu$, but the nucleolus has increased to $10\ \mu$, and is so filled with vacuoles that its stainable part is reduced to the rôle of mere film-like envelopes for the vacuoles, which give the nucleolus the appearance of a mulberry. As early as 1864, Balbiani¹ observed in *Phalangium opilio* that the nucleoli were foam-like, and that the vacuoles moved towards the surface, protruded, and then burst, discharging a fluid into the germinal vesicle. In *Epeira diadema* the contractile vacuoles of the nucleoli do not burst, but discharge their contents by means of little channels that open to the surface. Balbiani therefore looked upon the nucleolus as a sort of heart.

In larger ova still, the nucleolus, as such, has disappeared, leaving only fragments of nucleolar material, which may be scattered through the germinal vesicle or aggregated together into small clusters; later still, these fragments also seem to disappear. O. Hertwig² noticed similar fragmentation of the nucleolus in leeches. From this it will be seen that, from the time the nucleus attained its maximum growth, the nucleolus, though apparently increasing in size, was in reality in process of disintegration, its colourable material becoming less and less in amount as the vacuolation increased.

All these changes occur before the formation of the first polar body, and constitute a phenomenon of early maturation.

From what has been already said, it would seem that, previous to the commencement of reduction mitosis in these ova, it is essential that the nucleolus be removed in one way or another, either bodily by extrusion, or more commonly by vacuolation and fragmentation, with subsequent solution.

I have shown elsewhere (stomach of newt, etc.) that the nucleolus in all probability consists, in great part at least, of effete material, and that it increases in size during cellular activity. There soon comes a time, however, when the presence of larger quantities of nucleolar (effete) material would be injurious to the cell, and the nucleolus is then extruded into the

¹ Balbiani, C. R. *Société de Biologie*, 1864.

² O. Hertwig, *Morphologische Jahrbuch*, Bd. iii. Heft i.

protoplasm, either before or after vacuolation has made its appearance in it. A new nucleolus is quickly formed, beginning either just before or immediately after the expulsion of the old one, that is to say, new effete matter is produced, and continues in the nucleus until it again becomes excessive in quantity, when it is extruded in its turn, and so on.

In actively working cells like those of the cardiac glands of the stomach, etc., the extrusion of nucleoli may occur several times in the twenty-four hours; in less active cells, less frequently; and we can understand how a perfectly passive cell such as the ovum, which has only to grow, its food even being elaborated for it by the cells of the Graafian follicle, can tolerate the accumulation of a considerable amount of effete matter, until the time has come for it to enter into a more active stage of existence, and that stage seems to be reached when the germinal vesicle has attained its maximum growth. It then becomes imperative for the ovum that its accumulated effete products should be removed, in order that it may be in the best possible condition to undergo reduction mitosis and fertilisation.

I think that those who believe that the nucleolus plays any important part in cell life, either as a circulatory or nutritive element, are in error in the main, and that the nucleolus must be looked upon as consisting almost entirely of effete material resulting from cell activity and metabolism.

I append tables showing relative rate of increase of nucleolus, nucleus, and protoplasm, their true size at different stages of growth, etc., which I trust may be found of interest.

TABLE I.—*Showing true size of Nucleolus, Nucleus, and Protoplasm, calculated as spheres in cubic micro-millimetres. The volume of the nucleolus is deducted from that of the total nucleus; and that of the total nucleus from that of the total ovum.*

Stage	1	2	3	4	5	6	7
Nucleolus, .	4·18	33·5	65·4	113	179·5	268	523·6
Nucleus, .	519·4	2111·4	5524·8	8068·1	9023·1	8934·7	8679·1
Protoplasm,	3665·2	8161	23140·7	61387·9	68749·2	92957·8	121721·8

TABLE II.—*Relative Rate of Increase of Nucleolus, Nucleus, and Protoplasm, calculated from Table I.*

Stage	1	2	3	4	5	6	7
Nucleolus, . . .	1	8	15·38	27	42·87	64	125
Nucleus, . . .	1	4·08	10·63	15·53	17·37	17·20	16·70
Protoplasm, . . .	1	2·22	6·31	16·47	18·75	25·36	33·21

TABLE III.—*Ratio of Nucleolus to Nucleus and Protoplasm.*

Stage	1	2	3	4	5	6	7
Nucleolus, . . .	1	1	1	1	1	1	1
Nucleus, . . .	123·9	60·2	84·4	71·3	50·2	33·3	16·5
Protoplasm, . . .	875	243·5	353·5	542·7	382·7	346·7	232·4

TABLE IV.—*Ratio of Nucleus to Protoplasm.*

Stage	1	2	3	4	5	6	7
Nucleus, . . .	1	1	1	1	1	1	1
Protoplasm, . . .	7·05	3·86	4·18	7·60	7·61	10·40	14·02

FURTHER OBSERVATIONS ON THE ANATOMY OF
THE BRAIN IN THE MONOTREMATA. By G. ELLIOT
SMITH, B.A. (Cantab.), M.D. (Syd.), St John's College,
Cambridge. (PLATES X.-XII.)

It had been my intention not to add to the number of communications which I have already contributed on this and allied subjects during the last four years, until I might be in a position to write a fairly comprehensive monograph upon the whole central nervous system in the Monotremata and Marsupialia. But many of the statements which have been made in Professor Ziehen's recent memoir upon this subject¹ cannot be allowed to remain unchallenged. In a work which covers such a broad field, it is only natural that some errors of observation and interpretation should be made; and as the misinterpretation of the features of the brain in such an important order as the Monotremata is bound to have an influence upon the interpretation of the morphology in other groups of animals, no time should be lost in correcting such errors.

In his memoir Professor Ziehen honours my work by referring to it on numerous occasions. In many places he points out what he considers errors on my part; but as we shall see in the course of this contribution, most of these discrepancies are to be explained by the fact that Ziehen's material did not permit him to appreciate the true state of affairs, so that in imputing errors to me, he thereby proclaims on many occasions the inaccuracy of his own observations. The most peculiar instances of this are to be found in his description of the *pons Varolii* in *Ornithorhynchus*, in which he clearly overlooked the greater part of the true *pons*, and accused me of committing this mistake; and, again, in the confusion of the cranial nerves in *Ornithorhynchus*, which has led him to label the roots of the hypoglossal nerve "seitl. gemischten Systems," by which he means the spinal accessory series of nerve roots.

¹ Theodor Ziehen, "Das Centralnervensystem der Monotremen und Marsupialier." I. Theil. Makr. Anat. Semon's Zool. Forschungsreisen, iii. Jenaische Denkschrift., vi. 1897.

Then, again, in other places he attributes to me statements of which I am completely innocent. The most noteworthy instance of this is to be found on page 7, in which he imputes to me the ridiculous statement that the *locus perforatus* is identical in structure with the pyriform lobe, and then proceeds to disprove this fiction of his own imagination.

In the present contribution I shall take advantage of the occasion which has thus been imposed upon me, and give a short account of the features of the brain in *Ornithorhynchus*. Ziehen gives an excellent description of the gross anatomy of the brain in *Echidna*, but his account of the organ in *Ornithorhynchus* is not nearly so satisfactory, and hence I shall devote most of my attention to the latter, and merely add comparative notes to supplement Ziehen's observations on the former.

I shall postpone the discussion of the brain in the Marsupialia until a later occasion, because the limits imposed upon this contribution forbid the adequate consideration of this subject here. As Ziehen does not attempt to give a full account of the spinal cord, I shall also postpone the consideration of this part of the Prototherian nervous system for the present.

GENERAL ACCOUNT OF THE BRAIN IN ORNITHORHYNCHUS.

A brief account of the three figures which accompany this communication will convey a good general idea of the features of the brain in *Ornithorhynchus*. Then we shall be in a position to devote special attention to the parts of the subject which are of special interest and significance.

I would not have been able to make these figures so complete as they are now if the generosity of my friends Professor J. T. Wilson and Mr James P. Hill of the University of Sydney had not kept me well supplied with numerous well preserved brains of *Platypus*, in addition to large numbers of brains and spinal cords of *Echidna* and various Marsupials, the study of which has indirectly influenced my work on *Ornithorhynchus*. To Professor Parsons of St Thomas's Hospital I am also indebted for the head of an *Ornithorhynchus*, which enabled me to make a dissection of the cranial nerves, and verify my diagnoses of them, which were so strangely at variance with Ziehen's work. To these

three gentlemen I must express my sincerest thanks for their kindness.

The cerebrum of *Ornithorhynchus*, when viewed from above or from below, is of the conventional heart-shape, and presents a delusive resemblance, at first sight, to that of a bird. When viewed from above, the cerebellum presents a broad lozenge-shaped outline behind the cerebral hemispheres, and is slightly overlapped by the latter. Contrary to the opinion of Ziehen, the cerebellum completely hides the fourth ventricle, so that the opening of the central canal into the latter cannot be seen unless the cerebellum is displaced.

The dorsal aspect of the brain of *Ornithorhynchus* has been represented at various times by Meckel and Turner,¹ but the best idea of the exact shape of the cerebral hemispheres and olfactory bulbs and their relation the one to the other will be gained from an examination of Gervais' excellent figure of a cranial cast.² In the recent text-book of Zoology by Parker and Haswell there is also a good figure.³

These figures seem to indicate to what extent Ziehen's figure (22) of the dorsal surface fails to represent the actual appearance, although I must admit that the latter is the only figure which represents the central part of the cerebellum with any degree of accuracy. The projecting floccular lobes have been omitted from all these figures.

Fig. 1 represents a view of the ventral surface of the brain of *Ornithorhynchus* in which the *hypophysis*, the *lobus flocculi* on the left side, many of the cranial nerves on the right side, and the bulging of the left choroid plexus of the fourth ventricle have been removed in order to represent other features more clearly.

In front we find the ellipsoidal *bulbus olfactorius*, into the cephalic pole of which, a compact bundle of nerve fibres, the olfactory nerve, is inserted. The bulb is attached to the under surface of the apex of the cerebral hemisphere by the flattened *pedunculus olfactorius*. This appears to split into two bands, which diverge and embrace an elliptical protuberance of grey substance,

¹ This *Journal*, vols. xxvi. and xxx.

² Paul Gervais' *Mémoire sur les Formes Cérébrales propres aux Marsupiaux*, Nouvelles Arch. du Mus., T. v., pl. 14, fig. 17.

³ Parker and Haswell, *Text-book of Zoology*, vol. ii. p. 547, fig. 1136.

the *tuberculum olfactorium*. The mesial of the two bands immediately disappears from view in this figure by extending on to the inner surface of the hemisphere. The lateral band is continued backward on the ventral surface of the hemisphere as the *lobus pyriformis*, which describes a sinuous course, and consists of an anterior arc lying along the outer margin of the *tuberculum olfactorium*, and a posterior arc which curves nearer the mesial plane, and becomes swollen to form a tubercle (lying in the figure below the pointing line to the *corpus mammillare*), just before the lobe disappears under cover of the hind-brain. The outer margin of the pyriform lobe is formed in its whole length by the *fissura rhinalis*, which anteriorly becomes continuous with the cleft which separates the olfactory bulb and its stalk from the apex of the cerebral hemisphere. The anterior arc of the *lobus pyriformis* is also bounded on its mesial side by a deep cleft (*fiss. a*), which is often called the endorhinal fissure.

Behind the *tuberculum olfactorium* we find a quadrilateral depressed area, which constitutes the *locus perforatus anticus*. It is separated from the floor of the 'tween-brain by an oblique furrow, which forms the anterior limit of a little mesial triangular area, which is bounded posteriorly by the optic chiasma. Retzius has described this little triangular pouch in the brain of many mammals and in the human fœtus under the name "*area terminalis*," which I have adopted here.¹ Its mesial portion is formed by the ventral extremity of the *lamina terminalis*.

Behind the optic chiasma the floor of the 'tween-brain is depressed into an elongated sac-like *tuber cinereum* in the mesial plane, and in its posterior part we see the cut-lips of the *infundibulum* (*b*), from which the *hypophysis* has been removed.

On each side of the *tuber cinereum* the sloping surface of the *hypothalamus* may be seen disappearing under the *lobus pyriformis*. Emerging from under cover of the latter, one may see on each side the small oculo-motor nerve (III) proceeding obliquely across the *hypothalamus* toward the *tuber cinereum*. Behind the infundibulum we may see the *corpus mammillare* projecting in the depths of the deep cleft, which is caused by the head-bend in the embryo.

The large area of the base of the cerebral hemisphere, which

¹ G. Retzius, "*Das Menschenhirn*," 1896.

lies upon the outer side of the *fissura rhinalis*, is the *pallium*. It is completely devoid of true fissures or sulci. Opposite the middle of the anterior arc of the lobus pyriformis a shallow furrow (*f*) proceeds obliquely outward and backward. In it the middle cerebral artery is placed, and it may be analogous to the *fossa Sylvii* of other mammals. Opposite the hypothalamic region the ventral surface of the lobus pyriformis, and the adjacent area of *pallium*, which is shaded (*k*), is grooved to lodge the ophthalmic and maxillary branches of the huge trigeminal nerve, as they proceed forward to their respective foramina in the floor of the cranium.

A deep depression (*g*) is found in the *pallium* on the ventral portion of its caudal border, and it will be noticed that upon the right side the lobus flocculi of the cerebellum lies in the corresponding 'floccular fossa,' as we may call the indentation.

As the brain lies in the cranium, the lobus flocculi is placed in a peculiar little bony cage, formed by the petrous temporal. It is really this bony structure which is lodged in the floccular fossa. Upon the ventral surface of the hind-brain we find an enormous swelling on each side of the mesial plane and a deep intervening *vallecula*. As this swelling is intimately associated with the fifth nerve, I have called it the *tuberculum quinti*. The anterior extremity of this tubercle is full and rounded, and is separated from the cerebral hemisphere merely by a fold of dura mater, which forms part of the *tentorium cerebelli*.

In the caudal direction the *tuberculum quinti* gradually tapers, and hence appears as a large conical mass, lying upon the lateral aspect of the medulla oblongata. The *pons Varolii* is a narrow strand which crosses the *tubercula* at their widest and most prominent part, and dips into the deep *vallecula intertubercularis*. Here its antero-posterior extent becomes considerably increased, and its cephalic extremity projects forward toward the *corpus mammillare* as a beak-like process, which we may call the *rostrum pontis*. Emerging from the interval between the pre-pontal part of the *tuberculum quinti* and the *rostrum*, we find the motor root of the fifth nerve, which proceeds transversely outward across the tubercle to join the *ramus mandibularis* of the fifth nerve, as is shown in the enlarged scheme (fig. 1).

The sensory root of the fifth nerve is subdivided into two

parts, a lateral (the *ramus mandibularis*) and a mesial (the *ramus maxillaris*)—the conjoined maxillary and ophthalmic branches—which are inserted separately into the *tuberculum quinti*, in front of the pons. [Compare the left side of the fig. 1 with the scheme fig. 1.] The large projecting *lobus flocculi* of the cerebellum is seen lying upon the pons and the posterior part of the cerebral hemisphere on the right side, while on the left side its cut-stalk (*h*) is seen just on the outer side of the seventh and eighth nerves, which are attached to the medulla oblongata in their usual situation. Immediately below these nerves we find a line of roots belonging to the ninth, tenth, and eleventh nerves, which present the usual arrangement and situation. On the right side the choroidal fold (*c*) of the fourth ventricle may be seen projecting beyond the lateral margin of the medulla on the cerebellum. The delicate sixth nerve emerges from the *vallecula intertubercularis* a short distance behind the pons.

The anterior pyramidal tracts are flat and insignificant, and the decussating fibres are not collected into compact bundles, but are scattered over a length of 5 mm. The hypoglossal nerve (XII) arises in the usual manner by a series of roots, which emerge at the lateral margin of the pyramids. These roots extend as low as the ventral root (*c1*) of the first cervical nerve, which emerges at the lateral border of a very distinct anterior column (*d*).

Fig. 2 represents that surface of the brain of *Ornithorhynchus* which is exposed by a mesial sagittal section. In front we again see the *bulbus olfactorius* projecting beyond the apex of the hemisphere, from which it is separated by a deep cleft. Behind the lower part of the bulb we see the white mesial surface of the olfactory peduncle continued obliquely upward above the *tuberculum olfactorium* into continuity with the white district to which I gave the name *area præcommissuralis*. The latter proceeds backward as far as the thickened lamina terminalis, which contains the two round bundles of fibres, which constitute the dorsal and the ventral commissures. The lamina terminalis bends backward near its ventral extremity to reach the optic chiasma, and we can now understand how this part of the *lamina terminalis* forms the *area terminalis* in front of the optic chiasma

upon the base of the brain (fig. 1). In the interval between the *tuberculum olfactorium* and the *lamina terminalis* the precommissural area becomes continuous with the *locus perforatus anticus* (fig. 1).

Immediately in front of the upper extremity of the *lamina terminalis* the precommissural area becomes continuous with the cephalic extremity of the fascia dentata, which makes its appearance as a fusiform band above and in front of the *commissura dorsalis*. The *fascia dentata* is limited on its dorsal side by the hippocampal fissure, which separates it from the broad area of pallium. The pallium forms the greater part of the mesial surface of the hemisphere which extends backward over the *optic thalamus*, *mesencephalon*, and part of the cerebellum. From the cephalic extremity of the *fissura hippocampi* a shallow furrow proceeds obliquely forward to the deep cleft which separates the olfactory bulb from the pallium. This furrow separates the pallium from the precommissural area, and may be distinguished as the *sulcus limitans pallii*.

The anterior cerebral artery, after crossing the *locus perforatus anticus*, proceeds upwards across the *area præcommissuralis*, upon which it produces a furrow (*m*), and then reaches the hippocampal fissure, in which it proceeds backward. It gives off three very constant branches, which produce deep depressions in the pallium (*m*) as they traverse its surface to reach the dorsal aspect of the hemisphere.

The thickened *lamina terminalis* (containing the two commissures of the cerebral hemispheres) forms the anterior wall of the third ventricle. The roof of this cavity is formed by a thin epithelial fold, which has been represented semi-diagrammatically in the figure (*tela*) in order to avoid confusion. Its complex folds, which form the choroid plexus of the third ventricle, have not been represented, for the sake of clearness. The epithelial roof is attached to the cephalic corner of the upper thickened part of the *lamina terminalis*. In other words, it proceeds forwards, and forms a small *recessus superior*, which extends above the *commissura superior* in the same manner as is common in the Reptilia and Amphibia.

Posteriorly, the roof is attached to the little cord of transverse fibres which constitute the *commissura habenularum* or

commissura superior of Osborn, and which is attached to the anterior extremity of the little solid *epiphysis*, into which only a very slight *recessus pinealis* extends.

The floor of the ventricle is formed by the horizontal lower part of the *lamina terminalis* and the sac-like *tuber cinereum*, to which the conical bilobed *hypophysis* is attached posteriorly. [The downward extension of the *tuber cinereum* is slightly exaggerated in fig. 2.] Extending upward from the posterior part of the *hypophysis*, we find a thin lamina ascending to the large oval section of the *corpus mamillare*. This thin inframamillary lamina corresponds to the *eminencia saccularis* of G. Retzius, which, according to him, represents the *saccus vasculosus* of fishes.¹

The *corpus mamillare* becomes continuous dorsally with the mesially fused tegmental mass, which arches upward and forms the floor of the *aquæductus Sylvii*.

This anterior surface of the fused *tegmenta*, together with the *corpus mamillare* and what we may call the *lamina saccularis*, form the great part of the posterior wall of the third ventricle. The dorsal lip of the wide open anterior mouth of the Sylvian aqueduct is formed by the *commissura posterior*.

The cavity of the third ventricle has the customary vertical slit-like form. Immediately in front of the wide mouth of the *aquæductus Sylvii* we find the large mass of the *commissura mollis* bridging across the cavity. In the interval between it and the *epiphysis* we find upon the lateral wall of the ventricle the large pear-shaped bulging of the *ganglion habenulæ* (*habenul*). From the apex of the latter the large cord-like *stria medullaris* extends forward and arches downward, being here separated from the *commissura dorsalis* by the *foramen Monroi*. Around the lower margin of the foramen of Monro it appears to be continuous with the *columna fornicis*, but below this point neither of these fibre-bundles is visible in the mesial wall of the ventricle. [For the actual relations of these two tracts of fibres in this region, see fig. 6 in my memoir in last year's volume of this *Journal*, vol. xxxii. p. 36.]

Above the foramen of Monro we can see the *fimbria* extending

¹ Gustav Retzius, "*Das Menschenhirn*," 1896, and *Biologisch. Untersuch.*, 1895.

backward from the region of the dorsal commissure to reach the margin of the hippocampal formation. Above the *area terminalis* there is a depression in the lateral wall of the third ventricle; this is the *recessus opticus*. The floor of the *tuber cinereum* is also bulged out laterally in a sac-like manner. There is a vertical furrow on the lateral wall of the ventricle below the *commissura mollis*.

The roof of the aqueduct of Sylvius is formed by the quadrigeminal plate, and the broad flattened anterior and the small posterior quadrigeminal bodies may be seen projecting upon the lateral side of the middle line. The cerebellum has been drawn backward in the figure in order to expose the posterior quadrigeminal body.

The *tegmen mesencephali* is joined to the ventral surface of the cerebellum by means of the *velum medullare* in the ordinary manner. The minute fourth nerves (which are not shown in this figure) present the usual relations.

A very deep cleft separates the floor of the third ventricle from the region of the pons Varolii. In the roof of this cleft we find a large *corpus* (or *ganglion*) *interpedunculare*, which is opposite to the corpus mammillare. The small third nerve, which is not shown in this figure, issues in its usual position immediately in front of the interpeduncular body. The *rostrum* of the pons comes into contact with the *corpus interpedunculare*. Emerging in front of the pons we see the large *ramus maxillaris* and the smaller motor root of the fifth nerve.

In the depths of the interval between the *corpus mammillare* and the pons we can see the tubercle of the pyriform lobe [which is not labelled]. The anterior part of the pyriform lobe can be seen in front of the *tuber cinereum*.

I shall not enter into a detailed account of the cerebellum in this place, but shall deal with it in a separate paper subsequently. We may merely note in passing how markedly it differs from the conformation of the organ in all the Meta- and Eutheria.

Fig. 3 represents the lateral aspect of the brain of *Ornithorhynchus*, in which the postero-inferior part of the ovoid cerebral hemisphere has been dissected away together with part of the optic thalamus [leaving the cut surface *y* exposed] in order to

show the lateral surface of the brain stem which is overlapped by the hemisphere.

Once again we see the *bulbus olfactorius* projecting forward beyond the apex of the hemisphere proper. But this wall of the bulb is deeply invaginated along an oblique line (*x*) in a manner which I have described and figured elsewhere.¹ Analogous involutions of the whole thickness of the wall of the bulb producing 'complete fissures' are not unknown among placental mammals; for I have recently described such an involution upon the ventral surface of the bulb in the African Aard-vark (*Orycteropus*).²

Behind the bulb we see the anterior part of the pyriform lobe, its surface whitened by the thin layer of fibres of the *tractus olfactorius*. The pyriform lobe disappears from view immediately below the *fossa Sylvii* (*f*). Below the pyriform lobe we again see the *tuberculum olfactorium* as a narrow fusiform area.

Beginning at the bottom of the deep cleft between the olfactory bulb and the hemisphere, a deep groove ascends obliquely across the pallium, and divides into a branching system of channels, which become gradually fainter. These are caused by the peculiar large vein which drains away most of the blood from the brain, and which I have called the *vena magna cerebri*. The groove which it produces I have called the *sulcus venæ magnæ*. The distribution of these vessels has been admirably represented by Gervais' figure³ of a cranial cast.

Behind the upper part of the cut surface of the *optic thalamus* (*y*) we see the *corpora quadrigemina*. Upon the posterior part of the lateral surface of the broad flat *nates* we find a peculiar little knob. Behind and on a lower level than the *nates*, we find the relatively small and inconspicuous *testes*, overhung by the projecting beak-like process of the cerebellum. Extending obliquely forward from the *testes* to the cut surface of the *optic thalamus* we can see the posterior *brachium* (which is not labelled). Below the *brachium* and *testes* we see the lateral surface of the mid-brain, which is placed very obliquely, or even almost

¹ Elliot Smith, *Anat. Anz.*, Bd. xi. Nr. 6, 1895, p. 165, figs. 5 and 6.

² Elliot Smith, "The Brain in Edentata," *Trans. Linn. Society*, London, 2nd series,—"Zoology," vol. vii., 1898.

³ P. Gervais, *loc. cit.*, pl. 14, fig. 17.

vertically. The ventral or cephalic half of this surface is covered by a thin white coat of longitudinal fibres, which represent the *pes* of the *crus cerebri* and the *lemniscus*, which to the naked eye are indistinguishable the one from the other. For so diminutive are the proportions of the *crus cerebri*, that its fibres do not form any definite projection on the surface. The most dorsal (caudal) of this group of fibres, which probably belong to the *lemniscus*, proceed toward the posterior *brachium*.

The delicate trochlear nerve (IV) may be seen issuing in the usual manner behind the nates, and proceeding forward on the surface of the tegmentum. The larger oculo-motor nerve (III) may be seen to issue from the angle between the *crus cerebri* and the cut surface (*y*) of the thalamus. Immediately in front of the figure III we can see the lateral surface of the *corpus mamillare* below the cut surface of the thalamus, and below this again we can see the *eminentia sacularis* of Retzius (*w*).

The oculo-motor nerve, in its ventral course to reach the situation in which we have seen it on the base of the brain (fig. 1, III), proceeds across the lateral surfaces of the *corpus mamillare* and the *eminentia sacularis*. The statement of Ziehen, that in the Monotremes the third nerve appears to spring relatively far forward in the brain,¹ is not true. In both Monotremes the third nerve arises and follows a course immediately in front of the *corpus interpedunculare*, exactly as it does in other mammals. In fact Kölliker's figure 636² might have been drawn from a section of this region in *Ornithorhynchus* or *Echidna*, instead of in the rabbit (*Lepus*). The lateral surface of the mesencephalon or *tegmentum* is directly continuous with the large swelling of the *tuberculum quinti*. But a deep cleft separates the latter from the ventral part of the *tegmentum*, where this is coated by the fibres of the *crus cerebri* and *lemniscus*.

The part of the cerebral hemisphere that has been removed in this preparation would be lodged in a deep vallecule, 6.5 mm. deep and 3.5 mm. wide, which intervenes between the *tuberculum quinti* and the *optic thalamus*.

¹ Th. Ziehen, *loc. cit.*, Jena. Denksch., p. 147.

² A. Kölliker, "*Handb. der Gewebelehre des Menschen*," II. Hülft, Leipzig, 1896, p. 505.

Inferiorly, we can see the insertions of the two huge sensory divisions of the fifth nerve into their tubercle immediately in front of the pons. The latter ascends between the *ramus mandibularis* and the facial (VII) and auditory (VIII) nerves to enter the cerebellum under cover of the *lobus flocculi*. [The nerves VII and VIII, which lie in the shadow of the flocculus, have unfortunately become obscured in the reproduction of the drawing.] The line of roots of the glossopharyngeal (IX) and vagus (X) nerves may be seen in their usual position along a line joining the facial (VII) nerve to the spinal accessory (XI). The hypoglossal nerve (XII) may be seen coming around the *tuberculum quinti* in order to associate itself with the IX, X, and XI nerves, and all four nerves leave the cranium by the one large 'jugular' foramen.

ON THE SUPERFICIAL ORIGINS OF THE CRANIAL NERVES.

The first nerve is in *Ornithorhynchus* a single definite bundle of fibres inserted into the apex of the *bulbus olfactorius* in the usual Saurian manner.

In *Echidna* we find the nerve split up, as is customary in the mammalia, into bundles of fibres which ascend through a cribriform plate, and are inserted into the ventral surface of a large flat foot-like *bulbus olfactorius*.

The optic nerves are very small in both Monotremes, and especially in *Ornithorhynchus*, and the third, fourth, and sixth nerves are of correspondingly diminutive sizes, but present the typical superficial origins.

The trigeminal nerve is peculiar in both Monotremes in being inserted wholly in front of the pons. Garner's statement that they are inserted behind the pons is obviously erroneous.¹ Otherwise the nerve in *Echidna* presents the usual mammalian features. The extraordinary peculiarities of the fifth nerve in *Platypus* will be described in detail further on in this account.

The superficial origins of the facial and auditory nerves are found in the usual situation in both Monotremes. Ziehen could not find the *facialis* in *Ornithorhynchus*, and suggested that it may have been pushed nearer the middle line by the enormous

¹ Robert Garner, British Ass. Reports, 1858, p. 123,—"Zoology."

development of the fifth nerve.¹ This is not the case, for the nerve is placed in close contact to the mesial side of the auditory nerve at the lower border of the pons.

In his figure of the ventral surface of the brain of *Ornithorhynchus* Ziehen labels the roots of the hypoglossal (XII) nerve "Wurzellinie des seitl. gemischten Systems,"² and explains in the text that by this name he refers to the *accessorius* (page 49). In the same figure he refers to a point some distance external to the so-called *accessorius* by the figure 'XII'. This is obviously a misprint. The hypoglossal nerve in the brains of both *Ornithorhynchus* and *Echidna* appear after the usual manner in the groove at the lateral border of the pyramidal tract (fig. 1). Ziehen does not represent the vagus and glossopharyngeal nerves in this figure, and his account of them in the text is vague and unsatisfactory (pp. 49 and 50). But elsewhere he makes this extraordinary statement:—"Die nerven des seitlichen gemischten Systems entspringen dementsprechend—wiederum namentlich bei *Ornithorhynchus*—viel weiter ventromedialwärts als bei den übrigen Säugern."³

He does not give any hint as to whether this vague statement refers to the *accessorius* only, or to the IX, X, and XI nerves. It harmonises to such an extent with his suggestion concerning the *facialis* that perhaps he may refer to the IX and X nerves also. To this we may add that the ninth, tenth, and eleventh nerves are arranged in both Monotremes in the same manner as they are disposed in other mammals, and the enormous development of the fifth nerve has not appreciably altered their positions (see figs. 1 and 3). The eleventh nerve can be followed with a lens as far as the neighbourhood of the fifth cervical nerve roots, and in *Ornithorhynchus* its extent is 30 mm.

THE REGION OF THE MEDULLA OBLONGATA AND PONS VAROLII.

The peculiarities of this region of the brain in *Ornithorhynchus* may be mainly attributed to the following factors:—

- (1) The enormous development of the trigeminal nerve.

¹ Ziehen, *loc. cit.*, p. 47.

² Ziehen, *loc. cit.*, fig. 23, p. 34.

³ Ziehen, *Anat. Anz.*, xiii. Bd., No. 6, 1897, p. 173.

(2) The diminutive proportions of the bundle of fibres which forms the *pons Varolii*.

(3) The peculiar relation of the roots of the fifth nerve and the associated masses of grey matter to the pons.

(4) The diminutive proportions of the pyramidal tracts and the scattering of its decussating fibres.

In *Echidna* the trigeminal nerve is also large, but in comparison with that of *Platypus* it seems small. In *Echidna* the pons is not much bigger than it is in *Ornithorhynchus*, and the pyramidal tracts present similar features in the two genera.

Recent research has clearly demonstrated that a large proportion of the sensory fibres of the fifth nerve terminate in the neighbourhood of their insertion into the hind-brain by forming synapses with the nerve cells of a mass of *substantia gelatinosa* which collects around the incoming fibres.¹ In the brain of *Ornithorhynchus* this mass of *substantia gelatinosa* (which, with a total disregard for accuracy of expression, is commonly called the 'sensory nucleus' or even the 'origin' of the fifth nerve) attains enormous dimensions in correspondence with the large size of the nerve. So great is this mass of *substantia gelatinosa* that it cannot be hidden under the diminutive pons (as it is in other mammals), but bulges out as a prominent swelling both on the caudal and cephalic sides of the pons; and as this swelling presents relations in *Platypus* for which no exact analogy is found in any other animal, not even in *Echidna*, I have called it the *tuberculum quinti*.²

Many of the fibres of the fifth nerve do not end in this principal *synaptic ganglion* (if I may coin a new expression) of the nerve, but descend through the medulla and upper part of the spinal cord, and end freely in a downward continuation of the principal synaptic ganglion, which produces upon the surface a swelling usually known as the *tuberculum cinereum Rolandi*. The spinal root of the fifth nerve is arranged on a similar plan in *Ornithorhynchus*, and the tubercle of Rolando forms a huge pyramidal swelling, the apex of which is placed upon the lateral aspect of the upper part of the spinal cord. We readily recog-

¹ S. Ramon y Cajal, "*Beitrag zum Studium der Medulla Oblongata*," etc., German translation by Bresler, Leipsig, 1896.

² This *Journal*, vol. xxx. p. 487.

nise (figs. 1, 2, and 3) that the tubercle of Rolando in *Platypus* is identical with the post-pontal part of the *tuberculum quinti*. The latter attains such large dimensions that it forms the greater part of the ventral surface of the *medulla*. A transverse section through the *medulla oblongata* opposite the greatest prominence of the *tuberculum quinti* presents a very peculiar appearance. For it consists of two large circular masses 8 mm. in diameter, joined the one to the other by a bridge 5.5 mm. thick and 2 mm. wide, in such a manner that the dorsal surface, which is the floor of the fourth ventricle, is flat.

The trigeminal nerve has in *Ornithorhynchus* three distinct roots, which I have distinguished as the *ramus mandibularis*, *ramus maxillaris*, and *radix motorius* respectively. The mandibular root is inserted quite separately from the rest of the sensory root (figs. 1 and 3, *V. ram. mandib.*) into the *tuberculum quinti* immediately in front of the lateral half of the pons, and measures at the situation of its insertion 6.5 mm. + 1.5 mm. (in a specimen which had been preserved in Müller's fluid and subsequently in alcohol). The maxillary trunk represents the conjoined roots of the *nervus maxillaris* and the *nervus ophthalmicus* of the trigeminal; but as both these nerves are destined mainly for the supply of the upper jaw, I have called the trunk the *ramus maxillaris* (figs. 1, 2, and 3). It is inserted into the rounded apex of the pre-pontal part of the *tuberculum quinti*, slightly in front and to the mesial side of the *ramus mandibularis* (fig. 1, *V. ram. maxill.*). But just in front of their insertion these fibres are collected into a much more compact bundle, which presents a cross-section of 6 mm. × 4 mm. (figs. 1', 2, and 3). This maxillary root proceeds directly forward, and produces a deep groove (fig. 1, *k*) upon the ventral surface of the hemisphere, involving both the *pallium* and the *lobus pyriformis*. While the *ramus maxillaris* is placed in this groove, which it makes for itself, it divides into two branches—a smaller mesial ophthalmic nerve and a larger lateral maxillary nerve—which Meckel has accurately represented.¹ These two nerves almost immediately leave the cranium through their appropriate foramina, and their further course

¹ Meckel, "*Ornithorhynchi paradoxi Descriptio Anatomica*," Leipzig, 1826, tab. vii. fig. 4.

can be readily understood from the examination of even a macerated skull. It will then be seen that the ophthalmic nerve, as it passes forward in the temporo-orbital fossa, is separated by merely a thin plate of bone from the olfactory bulb, which is contained in its own recess of the cranial cavity. And the maxillary nerve is placed in the temporo-orbital fossa immediately on the ventro-lateral aspect of the ophthalmic nerve. The relation of these two branches of the trigeminal nerve bulb to the olfactory bulb is well shown in a figure which Dr Hill has given.¹ In his description of the brain Hill says—"To the outer side of the [olfactory] bulb lies the optic nerve, and to the outer side of this again the immense fifth nerve" (page 375). "Optic" is obviously a misprint for "ophthalmic" in this quotation.

The situation of the motor root of the trigeminal nerve in *Ornithorhynchus* is very peculiar. Its superficial origin is situated on the deep surface of the *tuberculum quinti*, that is, in the deep groove which separates this swelling from the mesencephalon. But, in order to reach the surface, it proceeds around the mesial border of the projecting pre-pontal boss of the *tuberculum quinti*, where the *ramus maxillaris* is inserted into the latter (fig. 2, *V. motor*). It then proceeds transversely in a lateral direction across the *tuberculum* (fig. 1), immediately in front of and parallel to the pons, and ultimately reaches and joins the *ramus mandibularis* just as this is leaving the cranium through the *foramen ovale*. In the scheme (1') which accompanies figure 1 the relations of the three roots of the trigeminal nerve, each to the others, and to the *tuberculum quinti*, is shown on an enlarged scale.

The two sensory roots of the nerve appear to be quite separate the one from the other, and hence there is not a single Gasserian ganglion, in the ordinary sense, in *Ornithorhynchus*. But the nerve cells from which the fibres composing these roots arise are scattered among the fibres of the two roots in their intracranial course. In the brain of a foetal *Ornithorhynchus* I found a definite Gasserian ganglion.²

¹ Alex. Hill, "On the Cerebrum of *Ornithorhynchus paradoxus*," *Philosophical Transactions of the Royal Society*, 1893, B. Plate 20, fig. 1.

² "The Brain of a Foetal *Ornithorhynchus*," *Quart. Jour. of Micros. Sc.*, vol. xxxix, N.S., pl. ii. figs. 1, 11, 12, and 13.

The *pons Varolii* in *Ornithorhynchus* is a small compact strand of transverse fibres, which arch across the large hill-like prominences of the *tubercula quinti*, and dip down into the deep valley which intervenes between these eminences. In this *sulcus intertubercularis*, as we may call the valley, the pons is produced in the cephalic direction into a beak, and here it attains its maximum sagittal diameter of 5 mm. When the pons attains the mesial border of the *tuberculum quinti*, its antero-posterior diameter has become reduced to 4 mm., and when it has reached the lateral border of the *tuberculum* its sagittal measurement has become further reduced to merely 2 mm. At the situation where the sagittal diameter is 3 mm., the thickness of the pons is scarcely 0.5 mm. Upon the lateral aspect of the *tuberculum quinti* it ascends between the *ramus mandibularis* of the fifth nerve and the eighth nerve to the cerebellum as its small middle peduncle. The mesial part of the *lobus flocculi* rests upon the middle peduncle in this situation, and produces a slight depression upon it (figs. 1 and 3).

The scanty literature of this subject contains a most extraordinary series of errors of observation and interpretation.

In 1826 Meckel gave an excellent figure of the base of the brain, in which he represented and correctly named the *pons*, and the "eminencia cui trigeminus laxè insidet": he also represented, but did not name, the motor root of the fifth.¹

Twenty-one years later Owen adopted, with very slight modifications, the figure in question, but he committed the strange error of calling the pons the "*corpus trapezoides*," and the motor root of the fifth the *pons*! Thus he says:—"Their [the *tubercula quinti* of this communication] anterior extremities are crossed by large trapezoid bodies (figured by Meckel as the pons Varolii), and anterior to those is the true 'nodus encephali,' which is narrow, in correspondence with the small lateral lobes of the cerebellum."²

Eleven years later Garner erroneously described the trigeminal nerve as attached behind the pons to the medulla in both Monotremes.³

¹ Meckel, *loc. cit.*, tab. vii. fig. 4.

² R. Owen, "*Monotremata*," Todd's *Cyclopædia of Anatomy*, vol. iii., 1847, p. 333, fig. 181.

³ R. Garner, British Association Reports, 1858, p. 123.

In 1896 the present writer correctly represented this region of the brain in *Ornithorhynchus*.¹

This figure, however, does not meet with the approval of Ziehen, who says concerning it:—"Die Abbildung der Hirnbasis von *Ornithorhynchus*, bei Elliot Smith (*Jour. of Anat. and Phys.*, vol. xxx. p. 487, fig. 12), ist wohl schwerlich ganz naturtreu. Auch reicht der Pons weiter nach vorn als Smith angiebt. Vergl. meine Darstellung, p. 45 ff." ² (*The italics are mine.*)

When Ziehen so positively affirms that my figure is scarcely correct, one naturally expects to find some definite statements to indicate the error. But on referring to page 45 of Ziehen's memoir, as he directs, we find the paragraph in question beginning thus:—"Die Feststellung der Grenze der Brücke bietet sehr grosse Schwierigkeit. Nicht einmal der einzelnen Hirnnerven lassen sich sofort ohne Zweifel identifiziren." Upon the next page he correctly indicates the anterior limits of the mesial part of the pons, and adds, "Die mikroskopische Untersuchung bestätigt diese Deutung." He then proceeds to describe a thin transverse layer of fibres which crosses the *tuberculum quinti*, but avoids expressing an opinion with the remark:—"Die definitive Entscheidung über die Frage, ob diese Faserschicht thatsächlich der Ponsformation homolog ist, bleibt natürlich der mikroskopischen Untersuchung vorbehalten," which hardly accords with the previous quotation from the same page. He then describes the anterior part of the *tuberculum quinti*, and is unable to find transverse fibres upon its surface. But he adds that the "abfallende Fläche" of this tubercle is covered (bedeckt) with transverse fibres. He says that the anterior edge of this layer of transverse fibres crosses the *crus cerebri* (Hirnschenkel) and is continued into the projecting mesial rostrum of the *pons*. To this he adds:—"Es kann keinen Zweifel unterliegen, dass damit der vorderer Rand des Pons vollständig gegeben ist. Diese vordere Rand liegt also auf der Basalfläche nicht frei, sondern ist wenigstens seitlich ganz in der tiefen Spalte zwischen Occipitalhirn und Tuberculum cinereum versteckt."

He then formulates the view that the large swelling which has appeared upon the lateral side of the pontine region has

¹ G. Elliot Smith, this *Journal*, vol. xxx. fig. 12, p. 487.

² Th. Ziehen, *loc. cit.*, Jena. Donkschr., p. 147.

separated the pontine fibres into two groups, one of which has been displaced backward and the other forward into the deep cleft between the cerebral hemisphere and the *tuberculum quinti*.

It is difficult to understand to which transverse fibres Ziehen refers as being thus hidden from view in the cleft between the *tuberculum quinti* and the cerebral hemisphere. The only definite bundle of fibres I can find in this situation is the motor root of the trigeminal nerve (*vide supra*). Although these fibres come into close topographical relationship with the beak-like anterior projection of the *pons* (Ziehen's "Zapfen"), the fifth nerve of course does not give fibres to the *rostrum*! In Ziehen's remarkable figure 23 (page 34), the motor root of the trigeminal is indicated as "ein kleiner Rest vom Trigeminus," but no attempt has been made to represent the mesial portion of the *pons*, and it is not clear from the text where Ziehen would place the posterior boundary of the *pons* in the middle line. In this figure he accurately represents the lateral portion of the *pons*, but does not name it; but he calls the pre-pontal part of the *tuberculum quinti* the "*pons*"! I presume that this extraordinary figure explains what Ziehen means when he says later on that the *pons* reaches further forward than I represented it (p. 14). But if the *pons* occupies the situation represented in this figure, what does Ziehen mean when he says, concerning the region which I have called the pre-pontal region of the *tuberculum quinti*,—"Auf dem Kamm lassen sich mit unbewaffnetem Auge und auch mit der Lupe querlaufende Nervenfasern nicht sicher nachweisen" (p. 46)? It is obvious that Ziehen has completely failed to recognise the *pons*, and has himself fallen into an error of a similar nature to that which he wrongly attributed to me. If he had recognised the true *pons*, he would hardly have represented the sixth nerve perforating the *pons*, as he does in his above figure 23. The true position of this nerve I have represented in figs. 1 and 2.

In further proof of Ziehen's complete failure to appreciate the real state of affairs, I might quote his remark on page 43:—"Dabei ergibt sich zugleich als bald die Thatsache, dass eine freiliegende Brücke im gewöhnlichen Sinne fehlt. Der vordere Ponsrand . . . ganz in die Tiefe gedrängt."

I have already referred to Owen's peculiar error in mistaking the motor root of the trigeminal nerve for the pons. In this connection it is interesting to quote a note of Ziehen's with regard to this point:—"Die distale Querfaserung deutet er [Owen] als Trapezkörper, die proximale *wie ich* [sic!¹] als Brücke." *Verb. sap.*

There is in *Ornithorhynchus* a compact and well-defined pons, which is placed in an exposed position upon the ventral surface of the hind-brain (figs. 1, 2, and 3).

I have entered somewhat fully into the consideration of this point, because Ziehen, in the full knowledge that my observations had been made upon an abundant supply of fresh material, has unjustly attributed to me a gross error in confusing one of the most obvious features of the brain.

The pons *Varolii* in *Echidna* closely resembles that of *Ornithorhynchus* in shape and general arrangement, but is slightly larger in the former. Thus in the mesial plane the pons varies in its sagittal diameter from 6 mm. to 7.5 mm. in different brains, but it rapidly shrinks, so that when it turns upward to become the middle peduncle of the cerebellum its diameter is barely 2.5 mm. in some brains, although in others it is as much as 3 mm. in diameter. Ziehen has accurately described and represented the pons in *Echidna*, and hence it is difficult to understand his observations upon *Ornithorhynchus* when we consider that the pons is so strikingly similar in the two brains. After referring to the pons in *Echidna*, Ziehen says:—"Die Verhältnisse bei *Ornithorhynchus* sind so complicirt und so einartig, dass sie zu einem messenden Vergleich sich nicht eignen" (p. 146).

Ziehen's difficulty in understanding the arrangement of the pons in *Ornithorhynchus* is probably due to the fact that the *tuberculum quinti* projects on the cephalic side of the pons. In order to distinguish the special condition which we find in *Platypus*, I have introduced this new term. But the *tuberculum quinti* is merely a *tuberculum cinereum Rolandi*, which is not confined to the post-pontal region of the hind-brain.

In *Echidna* the *tuberculum cinereum* is much smaller and the pons is slightly larger, and hence the former does not project

¹ The italics are mine.

forward beyond the latter, as is the case in *Ornithorhynchus*. In other words, *Echidna* presents the ordinary mammalian type of *tuberculum cinereum Rolandi*.

But Ziehen, who distinguishes the *tuberculum quinti* by the name '*tuberculum cinereum*' in *Ornithorhynchus*, calls the body which contains the spinal root of the fifth nerve in *Echidna* the '*eminentia olivaris*' (p. 32). And yet in the same memoir this writer adversely criticises Owen for committing the same error in *Ornithorhynchus*. Thus on page 47 we find the remark:—"Die hintersten Theil des Tuberculum cinereum hat er [Owen] fälschlich als Eminentia olivaris gedeutet." I may add that both Meckel and Owen clearly recognised this swelling in *Platypus* as an appendage of the fifth nerve, although they employed the term *eminentia olivaris*, which is associated with the topographically analogous but not homologous region of the human brain. Thus, after giving an excellent description of the *tuberculum quinti*, Meckel adds concerning it:—"Magnæ nervi trigemini evolutioni respondere videtur."¹

The swelling which Ziehen describes as '*eminentia olivaris*' in *Echidna* is the true *tuberculum cinereum Rolandi*, and its arrangement is exactly analogous to the larger post-pontal part of the *tuberculum quinti* of *Platypus*. Ziehen's error is all the more remarkable, seeing that he says that his statements are founded upon "zahlreiche, vorzugsweise nach Pal gefärbte Schnittserien älterer und jüngerer Tiere und Embryonen."² He describes the *eminentia olivaris* as a large swelling 4.5 mm. wide, which is placed immediately upon the lateral side of the roots of the hypoglossal nerve. On the same page, in a description of the dorsal aspect of the medulla, we learn that "Tuberculum cinereum Rolandi, Tuberculum cuneatum und Clava sind sehr schwach entwickelt";³ but in his contemporary communication to the *Anatomischer Anzeiger* he states (speaking of *Echidna*) that "die spinale Quintuswurzel ist stark ventralwärts verschoben und stellt einen Ziemlich schmalen, aber sehr langen streifen dar" (p. 173).

If we admit that the spinal root of the fifth nerve must be placed

¹ Meckel, *loc. cit.*, p. 33.

² Th. Ziehen, *Anat. Anz.*, Bd. xiii. Nr. 6, 1897, p. 171.

³ Th. Ziehen, *Jena. Denksch.*, *loc. cit.*, p. 32.

in the *tuberculum cinereum Rolandi*, these statements of Ziehen's are reconcilable neither the one with the other, nor with the condition which we actually find in the brain of *Echidna*.

But Ziehen's *eminentia olivaris* corresponds topographically and structurally to the *tuberculum cinereum Rolandi* of other mammals, and is the homologue of the post-pontal part of the *tuberculum quinti* of *Ornithorhynchus*, to which it presents the closest resemblance in all points except its size.

In the brains of both Monotremes, the descending root of the fifth nerve, the fibres of which can be seen upon the surface of the tubercle of Rolando, is crossed by a thin layer of transverse fibres, some of which are probably the homologues of the *corpus trapezoid-eum*, but there is no compact trapezoid body such as we find in the Meta- and Eutheria.

The *tuberculum quinti* projects forward in *Ornithorhynchus*, and becomes flattened against the ventro-caudal surface of the cerebral hemisphere, the *tentorium cerebelli* alone intervening. Hence, if we dissect away the posterior parts of the hemisphere, we find a broad sloping surface of grey substance 10 mm. long and 6 mm. broad, looking forward and upward toward the hemisphere (fig. 3). The ventral extremity embraces the *ramus maxillaris* of the fifth nerve, and comes into contact with the *rostrum* of the pons. Its mesial border is encircled by the motor root of the fifth nerve. The upper part of the tubercle lies in front of the *ramus mandibularis*, and slopes upward into continuity with the lateral surface of the *tegmentum* of the mesencephalon. The *tuberculum quinti* extends in the dorsal direction in front of the pons as far as the angle between the superior and middle cerebellar peduncles, under cover of the *lobus flocculi* (fig. 3).

THE FOURTH VENTRICLE

The floor of the fourth ventricle in *Ornithorhynchus* presents the usual lozenge-shape and measures 15 mm. long. The distance between the *columnæ cerebelli* (so we may distinguish the combined peduncles which support the cerebellum) is 10 mm., but as a lateral recess extends over the restiform body in the usual manner behind the *columna cerebelli*, the fourth ventricle attains a width of almost 15 mm. in this situation.

The floor is flatter than is usually the case in mammals.

The *eminentia teres* is very clearly defined by a slight sulcus which is parallel to the mesial longitudinal fissure.

Immediately to the inner side of the superior cerebellar peduncle there is a deep depression corresponding to an area about 5 mm. by 3 mm. It is caused by the lower part of the anterior lobe of the cerebellum.

A small ellipsoidal knob, 1 mm. high, 4 mm. long, and 2 mm. broad, is found on the floor of the ventricle at a distance of 3 mm. from the mesial plane, just opposite to the *recessus lateralis*. This I consider as the homologue of the body which in the Edentata I have called *tuberculum acusticum mediale*, and corresponds to what is usually called the *trigonum acusticum*. Ziehen regards it as the *tuberculum acusticum laterale*. In other words, he calls it *tuberculum acusticum* (page 47), and subsequently explains that it represents what he calls the *eminentia lentiformis* in Marsupials (page 148).

In my recent memoir on the brain in the Edentata I suggested the use of the terms '*tuberculum acusticum mediale*' in place of *trigonum acusticum* for the projection which corresponds to the dorsal or vestibular end-station, and the term '*tuberculum acusticum laterale*' to apply to the mass of grey substance which we find lying on the restiform body, including not only the lateral nucleus or so-called '*tuberculum acusticum*,' but also the accessory ganglion; in other words, the cochlear end-stations. These terms were introduced in the hope that the descriptive nature of the names 'lateral tubercle' and 'mesial tubercle' might help to do away with the confusion which the terms 'trigonum' and 'tuberculum' almost invariably create in the minds of students.

Now the topographical relationship of the tubercle in question to the peduncle of the cerebellum, and its position in the floor of the fourth ventricle, both point to its homology with the mesial and not the lateral tubercle as Ziehen supposes. Then, again, the large bundle of fibres which proceeds to this tubercle follows a course between the spinal root of the fifth nerve and the inferior peduncle of the cerebellum. In other words, it presents the same relations as the vestibular nerve in other animals presents in its course towards the *trigonum acusticum*, i.e., the

mesial tubercle. This view is further supported by the fact that a little crescentic body is found in *Ornithorhynchus* upon the dorsal surface of the restiform body, and embracing this peduncle as it bends into the cerebellum. This little body in its relations to the auditory nerve, as well as from its general topographical position, seems to represent a diminutive lateral acoustic tubercle.

But Ziehen says that the little tubercle in the floor of the ventricle represents the lateral tubercle, and the mesial one is to be found between this tubercle and the middle line. But if the lateral tubercle is so much more prominent than the mesial (*trigonum*), it is very strange that almost all the fibres of the auditory nerve should proceed to the former by the route which is usually pursued by the root going to the latter.

From such considerations it seems to me probable that the tubercle in the floor of the fourth ventricle represents the *trigonum acusticum* or mesial tubercle, and that the *tuberculum acusticum* of writers (lateral tubercle) is reduced to very diminutive proportions, especially in *Echidna*.

There are well-defined *ligulae* and *obex* in both orders. But concerning this structure in *Ornithorhynchus*, Ziehen falls into a peculiar error. He says that the obex is "nur angedeutet" (p. 47), and yet in the figure which illustrates his account (fig. 35) he clearly represents the large obex, but calls it *stratum transversum dorsale*; and in the text he says that the median fissure in the floor of the fourth ventricle is interrupted in posterior 3 mm. of its extent by a strand of crossing fibres (p. 47).

THE LAMINA TERMINALIS.

There are certain features of the *lamina terminalis* in the Monotremes which are of great morphological interest; and as I have discussed them only very imperfectly previously,¹ and as Ziehen has not added anything new to my earlier fragmentary descriptions, it is necessary to consider these features in some detail here.

Fig. 2 clearly shows the manner in which the thin *lamina*

¹ This *Journal*, vol. xxxii.

terminalis appears to expand as it ascends in order to form a matrix for the large commissures, and for this reason I spoke of this thickening of the *lamina terminalis* as the 'commissure-bed' in one of my earlier contributions.¹

I propose now to briefly consider the nature of this matrix. The ventricular cavity is everywhere lined by its own epithelium, and naturally the posterior and essential part of the *lamina terminalis* consists of such an epithelial layer. In the lower part of its extent, as for instance in the region of the *area terminalis*, this epithelial wall is further thickened and strengthened by a thin layer of tissue, which is mainly of a neuroglial nature. But as it extends dorsally, we find that there is added to the anterior surface of this true *lamina terminalis* a mass of grey substance, in which numerous nerve cells and fine nerve-fibres are found.

Now, this mass of grey matter must be derived from one of two sources. It must be formed either by a proliferation of the cells which constitute the primitive *lamina terminalis*, or it must be derived from the neighbouring mass of grey substance, the surface of which I have called the precommissural area. Now, the fact that the histological structure of this matrix or thickening of the *lamina terminalis* agrees so closely with that of the neighbouring mass of grey substances, inclines us to believe that this thickening or 'commissure-bed' is produced by an invasion of the primitive *lamina terminalis* by nerve cells from the neighbouring (*paraterminal*) body of grey substance which apply themselves to the anterior surface of the true *lamina terminalis*. This is what I intended to express by the term 'thickened *lamina terminalis*.'²

This view of the nature of the *lamina terminalis* in the Monotremes is strongly supported by the study of the phases of its development in Marsupials and other mammals, and was first suggested to me by a comparison between the conditions prevailing in the Reptilia with that found here.³ In my early studies of this problem I was led to the belief that this 'commissure-bed' became converted into the *septum lucidum* in Eutheria by its growth and subsequent stretching by the expanding corpus cal-

¹ This *Journal*, vol. xxx. p. 190.

² *Ibid.*, vol. xxx., and elsewhere.

³ *Ibid.*, vol. xxx.

losum;¹ but a fuller knowledge of the history of the development of the corpus callosum and *lamina terminalis* in the Eutheria convinced me of the fallacy of that view. In communicating to this *Journal* last year what I believe to be the true history of the mode of formation of the septum lucidum from the paraterminal ganglionic mass, the surface of which forms the *area præcommissuralis*, I unintentionally neglected to announce that my attitude toward this problem had changed, and thereby I rendered myself liable to the charge of inconsistency.

One of the most significant features in this region of the brain is the presence of the little *recessus superior*, which is of great phylogenetic interest. For here we find reproduced in a mammalian brain a feature which is clearly a persistence of the original Saurian or Pro-mammalian condition.

The anterior wall of this little supracommissural recess is obviously the homologue of the structure which Burckhardt has called the *lamina supraneuroporica* in some of the lowlier vertebrates.² Its recognition in a mammalian brain is a fact of some significance to the morphologist.³ The *lamina terminalis* and the *recessus superior* present similar features in *Echidna*.

Before leaving the consideration of the *lamina terminalis*, I must protest against the use of the term '*commissura superior*,' which Ziehen applies (p. 37 and elsewhere) to the dorsal or hippocampal commissure. The term '*commissura superior*' has been previously applied by Osborn to the *commissura habenularum*, and is commonly used in this sense at the present time not only in America and this country, but also among some German writers. When we recall that among many Reptiles and Amphibia the habenular commissure is in close topographical relationship to the hippocampal commissure and that they have even been mistaken the one for the other on several occasions, the singular inappropriateness of the use of the term '*commissura superior*' in the sense in which Ziehen employs it is obvious. It

¹ R. Burckhardt, *Der Bauplan des Wirbelthiergehirns*, Morph. Arbeiten hrg. v. G. Schwalbe, Bd. iv., 1894.

² Compare, in this connection, my account of its condition in the fetus, "The Brain of a Fetal Ornithorhynchus," *Quart. Journ. Micr. Sc.*, vol. 39, 1896.

³ "Eine besondere Fissura bulbi olfactorii lateralis ist scheinbar nicht vorhanden," *loc. cit.*, p. 86.

is for this reason that I have attempted to consistently employ the term '*dorsal*' instead of '*superior*.'

THE BULBUS OLFACTORIUS.

From Ziehen's account, it is obvious that all his specimens of the brain of *Ornithorhynchus* lacked either the whole or the greater part of the olfactory bulb. In his figures 22, 24, and 26 the whole of the bulb has disappeared, and the structure he labels '*bulbus olfactorius*' is the stump of the '*pedunculus olfactorius*.'

It is difficult to understand also how the bulb could occupy the position in which he represents it in figures 23 and 27. He says that "die Lobi olfactorii springen über den Stirntheil der Grosshirnhemisphären nicht vor," without adding any note to say that Meckel, Owen, Hill, Turner, and the present writer had previously represented it projecting beyond the hemisphere. A glance at the cranial cavity of *Ornithorhynchus* would show him that the bulb *must* project beyond the hemisphere.

When Ziehen says that the bulb is probably not separated from the rhinencephalon by a furrow,¹ one is inclined to believe that the whole of the bulb must have been knocked off his specimen. In one of my specimens in which this had happened the anterior part of the peduncle was flattened so as to resemble the appearance represented in fig. 23.¹

THE PYRIFORM LOBE.

In both Monotremes the pyriform lobe is separated from the pallium by an unusually deep and well-defined rhinal fissure. In addition the olfactory tract which is placed upon the surface of the anterior part of the lobe consists of a broad scattered series of fibres, which are not collected into a compact strand, as is the case in all other lowly organised mammals. The features

¹ In the copy of his memoir, which the author kindly sent me, he has added in handwriting, on p. 36, "Vielmehr ist der Bulbus olfactorius gegen das Rhinencephalon nicht scharf abgegrenzt." To this I may say that there is a distinction as well defined as there is in the Rabbit or Cat.

of the pyriform lobe itself present many other peculiarities which distinguish it from that of all other mammals.

In *Ornithorhynchus* the uniformity in the structure of the whole pyriform lobe long ago convinced me of the absurdity of limiting the term *lobus pyriformis* only to that part of the lobe which is on the caudal side of the region of the *vallecula Sylvii*. In my contributions to this *Journal* in 1896,¹ I therefore suggested that the term should be extended to the whole of the band, which is obviously part of the same histological formation. But there is absolutely no foundation in any of my writings for the ridiculous statement, which Ziehen² attributes to me, that the *substantia perforata* presents the same structure as the pyriform lobe.

Ziehen, again, says that my figure of the mesial surface of the hemisphere of *Ornithorhynchus* in this *Journal*³ is "nicht ganz correct," but he does not explain what is wrong in the figure, but extols his own figure (26, p. 36) as "naturgetreu."⁴ I fail to see the justice of this comment, but may observe that if my figure errs, Ziehen's figure not only repeats the supposed errors, but in addition commits some genuine mistakes, as a comparison with fig. 2 of the present contribution clearly shows.

THE TUBERCULUM OLFACTORIUM.

At the beginning of my investigations in 1894 I sought for some suitable word in order to define this well-defined region of the brain, and finally adopted Kölliker's term '*tuberculum olfactorium*' as the most appropriate, and then I proceeded to define its limits more accurately than this had been done previously. In my earlier paper in 1896 the limits of the area were not definitely marked off, but three months later⁵ I accurately defined the limits of the region, and separated it from all the surrounding areas. And yet in Ziehen's memoir, which appeared in December 1897, *i.e.* seventeen months after the latter contribution, we find these remarks:—"Ich kann Elliot Smith nicht beistimmen, wenn letzteres [*tuberculum*

¹ *Loc. cit.*, vol. xxx.

² Ziehen, *loc. cit.*, p. 7, *Jena. Denksch.*

³ Vol. xxx. fig. 1, p. 159.

⁴ Ziehen, *loc. cit.*, p. 35.

⁵ This *Journal*, vol. xxx., July 1896, p. 468.

olfactorium] mit dem Locus perforatus anticus Vicq d'Azyr's identificirt (*Journ. of Anat. and Physiol.*, vol. xxx. p. 186). . . . Broca's espace quadrilatère deckt sich nicht ganz damit."¹

My second memoir in the July number of the previous year's *Journal* clearly shows that I had not confused the areas in question, and I submit that my statement to which Ziehen objects is well founded. I am unable at the present moment to consult Vicq d'Azyr's work, but I may quote the following passage from the writings of Broca to justify my original statement:—"Lorsqu'on examine la face inférieure de l'hémisphère, on y aperçoit l'espace quadrilatère, limité en avant par les deux racines olfactives blanches, . . . Cet espace quadrilatère, . . . est l'analogue de l'espace décrit par Vicq d'Azyr, dans le cerveau humain, sous le nom d'espace perforé. Il est occupé, chez les animaux osmatiques, par une substance grise assez épaisse, qui s'insère à la fois sur l'angle de séparation des deux racines blanches, . . ."²

Later we find Broca speaking of the *tuberculum olfactorium* as "l'espace quadrilatère," and the region of the "area depressa" or *locus perforatus* he calls the "bandelette diagonale de l'espace quadrilatère." Many other instances might be quoted from other writers to show that the terms 'quadrilateral space' and 'anterior perforated space' were loosely employed to include the '*tuberculum olfactorium*'; and even to the present day, is it not a fact that we still use Vicq d'Azyr's term in Human Anatomy in this sense?

In criticising my statement that the *tuberculum olfactorium* is larger in *Echidna* than it is in *Ornithorhynchus*, Ziehen comes to the conclusion that it is relatively larger in the latter.³ In my specimens (preserved in Müller's fluid, and subsequently in alcohol) the tuberculum in *Echidna* varies in breadth from 6·5 mm. to 7 mm. in different specimens, while the sagittal diameter varies from 5·5 to 6 mm.; while in *Ornithorhynchus* the corresponding measurements are 2·5 mm., 2·75 mm., and 5 mm.-5·5 mm. But the mere superficial area is not by any means the most important factor in estimating the size of the

¹ Ziehen, *loc. cit.*, p. 14, note.

² P. Broca, *Mémoires sur le Cerveau de l'Homme*, Paris, 1888, p. 392.

³ *Loc. cit.*, p. 142.

tuberculum olfactorium, otherwise we might describe it as enormous in the anosmatic Cetacea, in which it is practically non-existent. For the corpus striatum comes to the surface in this situation, and may receive only a very thin coating of cortex, as in the case of *Ornithorhynchus*. But the plump *tuberculum olfactorium* in *Echidna* is of a very different nature, and resembles that which is found in the highly macrosmatic Eutheria, instead of being merely a thinly-clad bulging of the *nucleus lenticularis*. Here, again, I maintain the accuracy of my original statement.

Yet once more Ziehen challenges a statement of mine concerning this region. We have seen that the *fissura endorhinalis* (fig. 1, *fiss. a*), which separates the *tuberculum olfactorium* from the *lobus pyriformis*, extends backward and completely separates the *locus perforatus* from the pyriform lobe. In *Echidna* the *fissura endorhinalis* does not extend so far back, and hence the *locus perforatus* is in free communication with the pyriform lobe, as it is in all other mammals. To this Ziehen remarks, "die Angabe von Elliot Smith (*Jour. of Anat. and Phys.*, vol. xxx. p. 468) kann ich nicht bestätigen."¹ Nevertheless, it is a fact.

THE REGION OF THE MID-BRAIN AND OPTIC THALAMUS.

The only observation which I desire to make upon this region of the brain in the Monotremes is the fact that no definite projection corresponding to the *corpus geniculatum mediale (posticum)* is visible in either Monotreme. The *corpus geniculatum laterale* is only faintly marked in *Echidna*, and cannot be certainly recognised macroscopically in *Ornithorhynchus*.

The large *ganglion habenulæ* and the associated *ganglion interpedunculare* merely need to be noted.

In *Echidna* the *epiphysis* is a thin-walled pouch; in *Platypus* it is a solid mass.

Ziehen says he has clearly seen a *tractus peduncularis transversus* in *Ornithorhynchus*.² I believe that this statement is erroneous.

¹ *Loc. cit.*, p. 142.

² *Ibid.*, p. 43.

THE CEREBELLUM.

Although Ziehen has been able to give us a minute account of the configuration of the cerebellum in *Echidna*, the condition of his material unfortunately forbade him giving more than very imperfect notes concerning the organ in *Ornithorhynchus*.

The full discussion of this organ I must postpone for a further communication; but I may here express my disagreement with Ziehen's interpretation, and the process of reasoning by which he attained these results.

CONCLUSION.

It is now possible to state in a concise manner the most salient features of the brain in the Monotremata, taking into consideration not only the features discussed in this communication, but in addition those characters which I have previously described.

We may consider these features under two headings:—(A) in comparison with other mammals, and (B) in comparison with reptiles.

A. 1. In comparison with the Marsupialia, Insectivora, Cheirop-tera, Edentata, and Rodentia, we must admit that the Monotremata have a large cerebral cortex, the size of which greatly exceeds that of many other mammals.

2. If we admit that the number of fibres issuing from the pallium affords an index of the quality or degree of histological perfection of this cortical area, it is obvious that in the Monotremata the cortex must be of poor quality in comparison with that of all other mammals, because the large cortex gives rise to a very small internal capsule, *crus cerebri*, and pyramidal tract.

3. These observations point to the conclusion that, in order to meet the demands which its zoological position and mode of life imposes upon it, the Monotreme develops a cortex which rapidly increases in quantity, instead of becoming more highly elaborated.

4. This is especially so in the case of *Echidna*, which, for an animal of its size and lowly status, has an enormous pallium, which exhibits numerous sulci. But it is a very significant fact that the arrangement of these sulci does *not* conform to the plan

which, with relatively slight variations, prevails throughout the large group of Meta- and Eutheria.

5. The features of the pyriform lobe, the *tractus olfactorius*, and the *fissura rhinalis* are quite distinctive

6. The fact that the supra- and precommissural parts of the hippocampal arc (especially in *Ornithorhynchus*) are larger and better developed than the descending part of the arc, is distinctively Prototherian.¹

7. The absence of a projecting fimbria and the attachment of the choroidal fold at the margin of the fascia dentata are unique features.

8. The round or oval shape of the *commissura dorsalis* (vel *hippocampi*) in sagittal section is characteristic of this order.

9. The attachment of the roof of the fore-brain to the anterior lip of the thickened upper extremity of the *lamina terminalis* so as to form a supracommissural diverticulum of the third ventricle (*recessus superior*), is a significant feature which may be shared by some marsupials (*Didelphys*? *Perameles*? *Notoryctes*? *Phascogale*?), but is certainly not common to all the marsupials.

10. In comparison with the size of the cerebral cortex, the *pons Varolii* is small.

11. The lateral parts of the cerebellum are small, and those regions of the cerebellum which in the Eutheria show a progressive increase in size and complexity are peculiar in the Monotremes, by reason of their diminutive proportions and the paucity of fissures.

12. The plan of the cerebellum in the Monotremes is in marked contrast to that which is common to the whole of the Metatheria and Eutheria (*vide* "The Brain in Edentata," *Trans. Linn. Society*, London, 1898).

13. There is the closest agreement between the structure of the cerebellum in *Echidna* and *Ornithorhynchus*. The fact that in the former the floccular lobe is sessile, and in the latter pedunculated and encapsuled in a special bony case, is of little systemic significance, because such contrasts are not uncommon elsewhere among members of the same family. [I have recently recorded an example of this in the family of Anteaters, "The Brain in the Edentata," *loc. cit.*]

¹ This *Journal*, vol. xxx.

14. The absence of a projecting *corpus geniculatum mediale*, the slight prominence of the *testes*, the (possible?) diminutive proportions of the lateral acoustic tubercle, and the fact that the *corpus trapezoidum* is not a definite and compact bundle, all seem to point to a poorly developed central (or cortical) auditory path in the Monotremata in comparison with other mammals.

15. It is impossible to say definitely whether the habits of life of the animals, and the resultant diminution of visual acuity, are sufficient to account for the dwindling of the *corpus geniculatum laterale* and the flatness of the *nates*.

We may safely say that every region of the brain in the Monotremata shows some peculiarity of structure which enables the observer to distinguish it from the corresponding part of any other mammal, and which indicates the wide gap which separates the Prototheria from the Meta- and Eutheria.

B. 1. The presence of a definite pallium, which produces an internal capsule, crus cerebri, and pyramidal tract, and the existence of a pons, indicate an advance beyond the Sauropsidan to a distinctly mammalian status.

2. The features A. 6, 8, and 9, mentioned above, are distinctly Saurian, but the degree of elaboration of the hippocampal formation is characteristically mammalian.

3. The dwindling of the lateral parts of the cerebellum in the Monotremata is a slight approximation to the Sauropsidan condition, although the cerebellum in Monotremes is very much closer to the mammalian than it is to the Saurian type.

4. The diminutive size of the geniculate bodies and the smallness of the *testes* in the Monotremata probably indicate that the latter have not yet completely attained to the fully-developed mammalian position, but retain some suggestion of the Saurian status.

5. The olfactory bulb and nerve in *Ornithorhynchus* afford a peculiar instance of the persistence of the Saurian type. Many of the features of the brain are more or less directly the expression of the mode of life of their possessor.

As *Ornithorhynchus* usually ventures out only at dusk, and *Echidna* is nocturnal in its habits, it is not surprising to find that their visual acuity is diminished, their eyes and optic

nerves small, and the parts of the brain associated with them also diminutive.

In neither Monotreme can the auditory nerve be called 'large,' nor, at the same time, is it sufficiently small to account for the peculiar features of the *tubercula acustica*, and of the mid-brain. The aquatic mode of life accounts for the relative smallness of the olfactory bulb and lobus pyriformis in *Ornithorhynchus*; and the dominant influence of the sense of smell in a terrestrial, insect-eating mammal sufficiently explains the immense size of the olfactory bulb and the lobus pyriformis in *Echidna*.

But in the aquatic *Ornithorhynchus* the sense of smell does not exercise the dominant influence, as it does in *Echidna*. The visual and auditory senses can lay even less claim than the olfactory sense to this rôle. There can be little doubt that the predominant sense in *Ornithorhynchus* is that of touch, and the chief instrument of this sense is the broad expanse of skin which covers the snout, and which is as soft and delicate as a baby's cheek, and infinitely more sensitive, in virtue of its rich supply of nerve filaments from the enormous trigeminal nerve.

It can easily be conceived that as the animal spends much of its time in dark, subterranean channels, where impressions of sight and hearing avail little, that the sense of touch should be of most service, and, together with the sense of smell, should be a guide sufficient to the needs of this strange creature. For although the sense of smell is not predominant, the animal is unquestionably macrosmatic, like all other lowly animals, in spite of Ziehen's opposition to this view (*loc. cit.*, p. 139, 2nd note).

But when at dusk the animal leaves its burrow and takes to the water, the sense of smell is of little avail, and the creature may be seen swimming about upon the surface of some quiet pool, with its sensitive beak just below the surface of the water, responsive to every ripple which disturbs the surface. At such times vision and hearing can be but accessories to the more acute sense of touch.

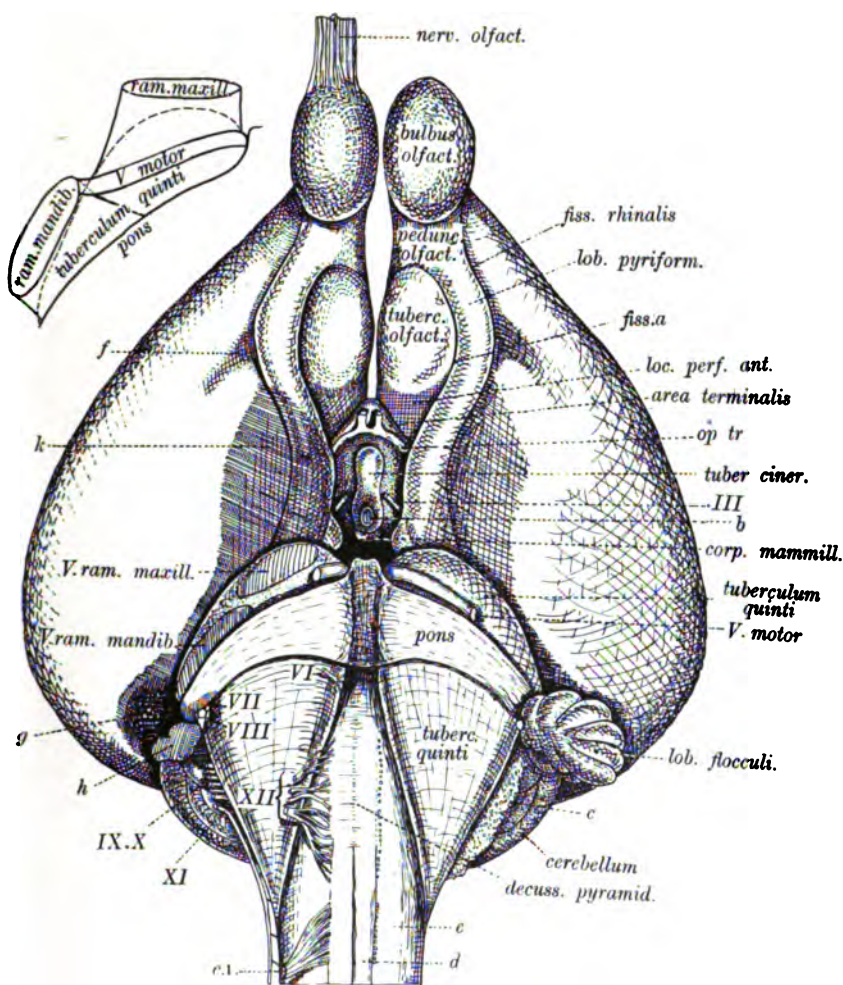
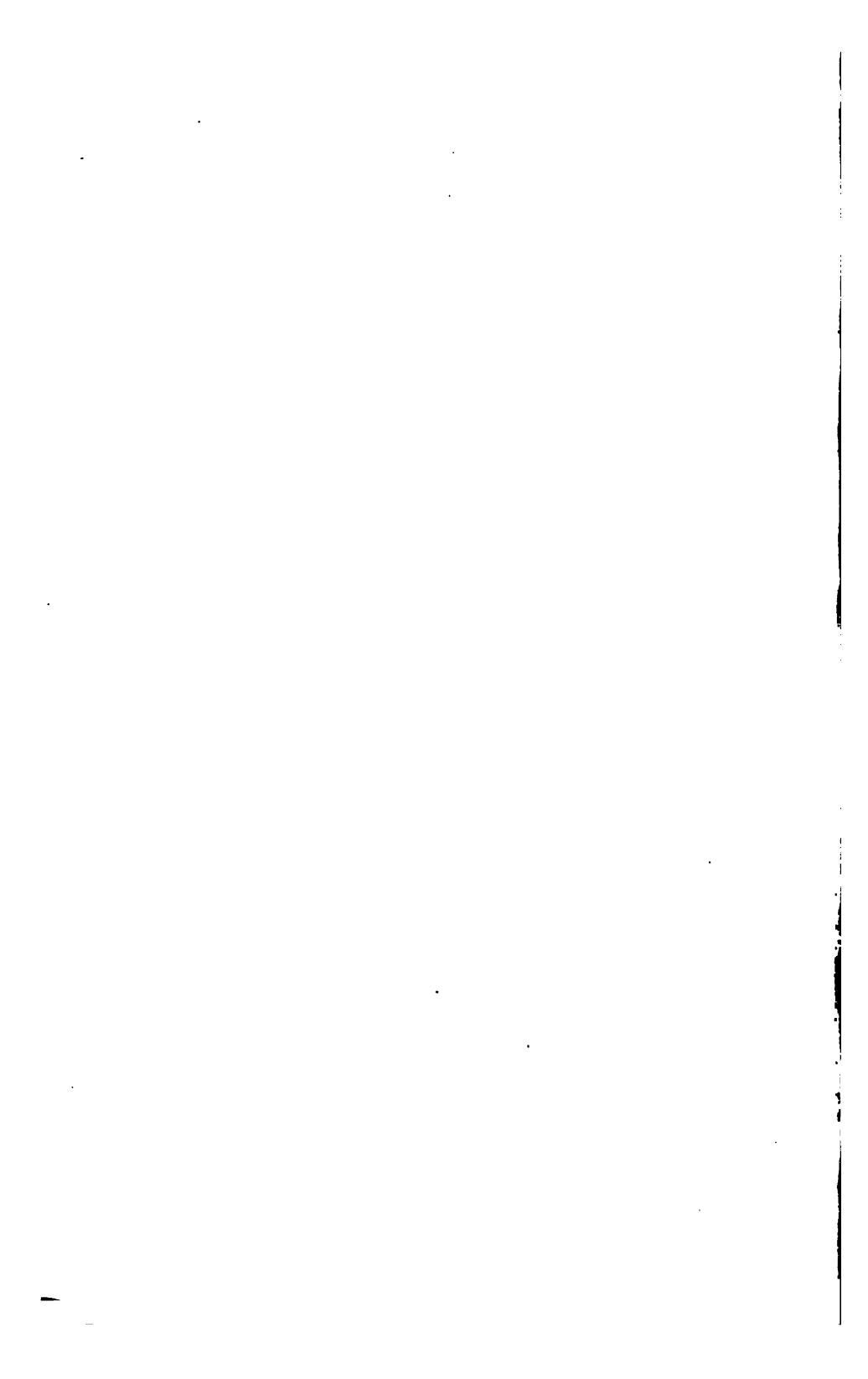


FIG. 1.—The base of a brain of *Ornithorhynchus*. Magnified 3 diameters.

FIG. 1'.—A scheme of the insertion of the fifth nerve.



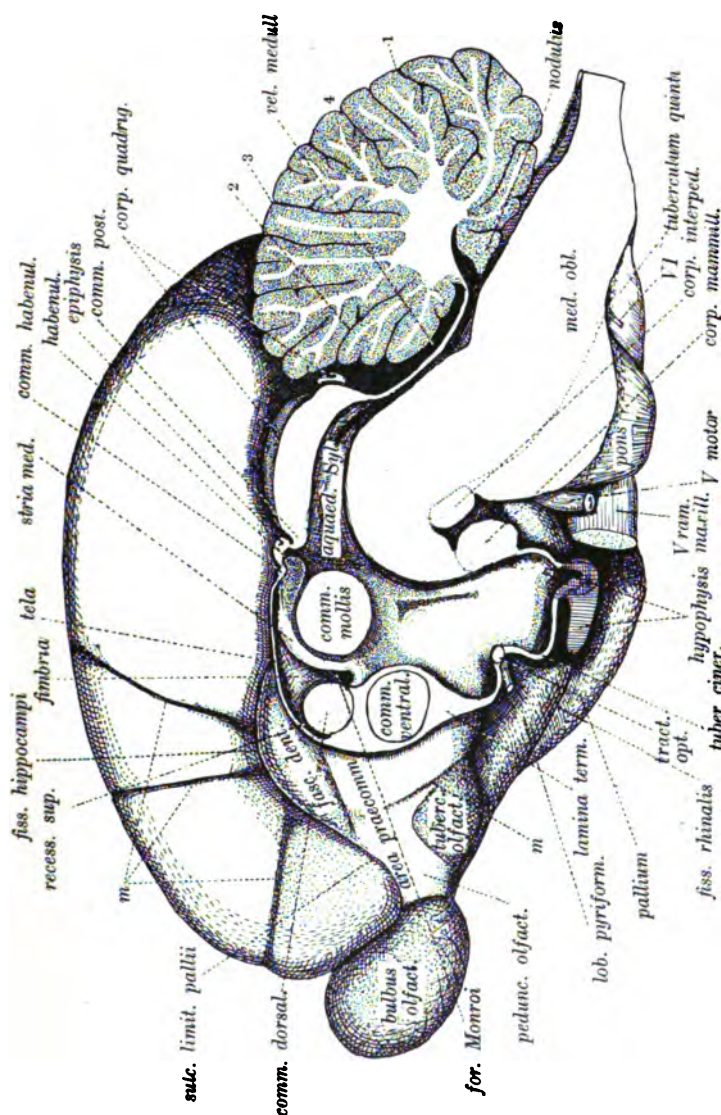
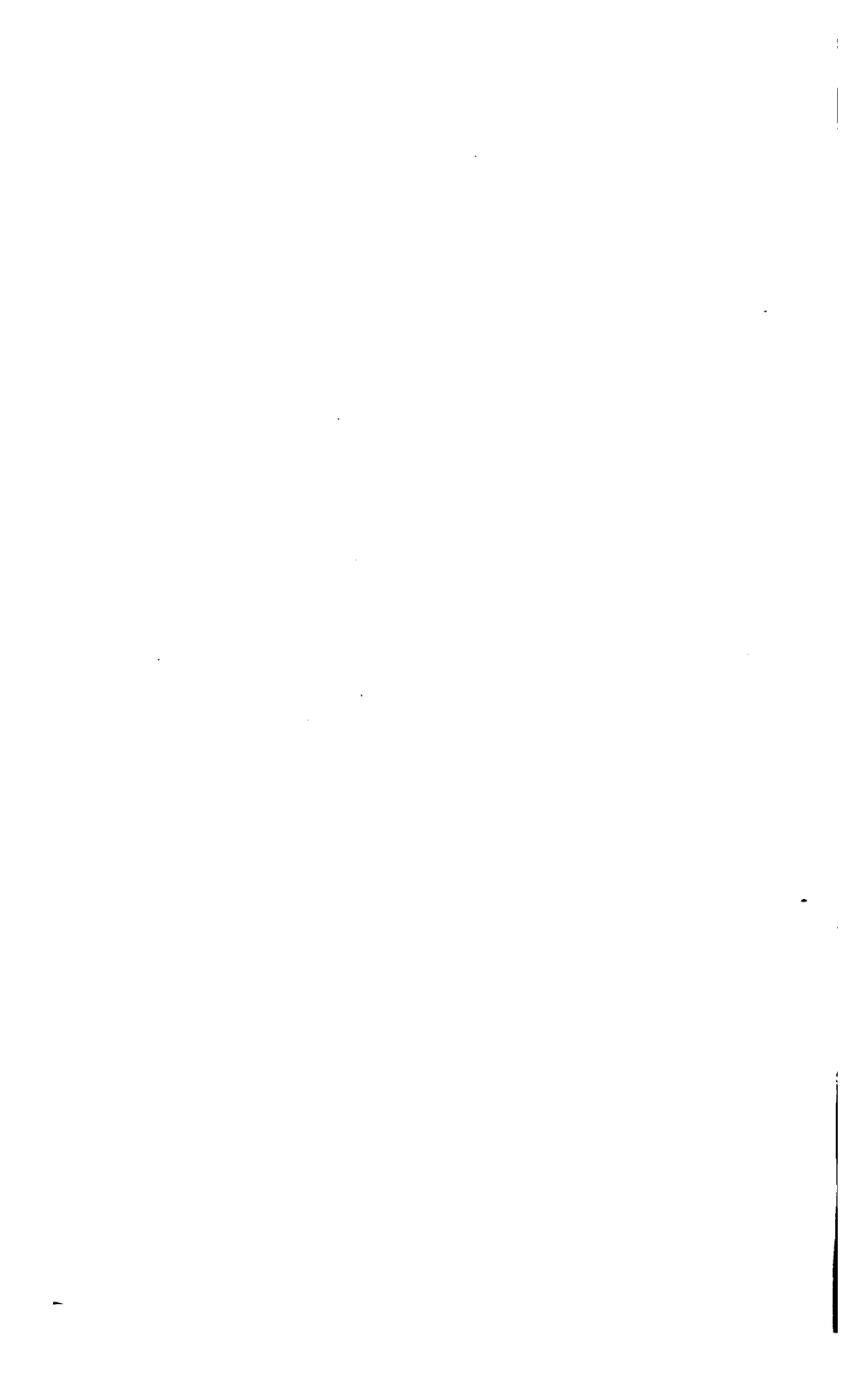


FIG. 2.—The surface of the brain of *Ornithorhynchus*, exposed by a mesial sagittal section. Magnified almost 4 diameters.



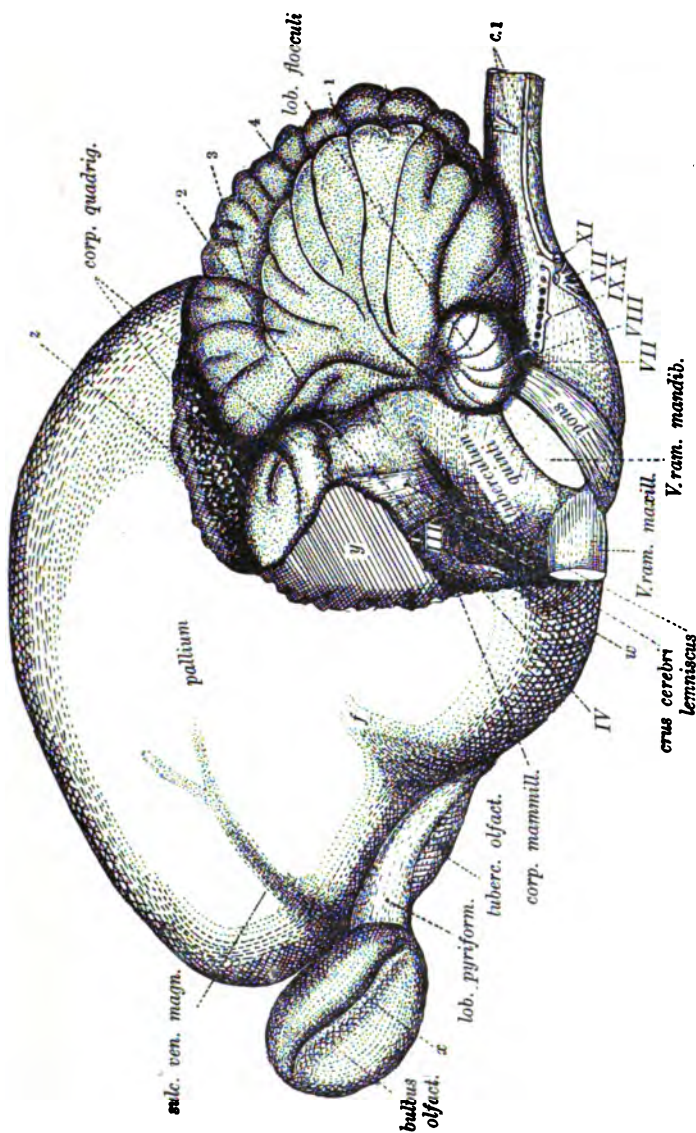


FIG. 3.—The lateral surface of the brain of *Ornithorhynchus*. Part of cerebral cortex and optic thalamus (*y*), removed to show the mid-brain. Magnified almost 4 diameters.

ARCHÆOLOGIA ANATOMICA.

III.

THE VEINS OF THE FOREARM.

THE superficial veins of the body must have been among the parts observed by the earliest medicine men, even before they began to make any systematic study of anatomy. Galen has remarked of these that they can be seen in man without dissection, and we are told by Celsus that the letting of blood from these veins was an ancient practice. Several treatises on the veins were composed by ancient Greek authorities: Syennesis, Dionysius, and Polybus of Cos wrote works of this nature. A part of the tractate of the last-named author is preserved, with extracts from those of the two other writers in Aristotle's *History of Animals*, book 3, ch. ii., and the work itself is sometimes included among the spurious works attributed to Hippocrates. Brentius's Latin translation of it is included in Cratan-der's Basel edition of the works of Hippocrates, 1526.

One of the veins of the arm is named the internal cubital in the treatise *de Victu Ratione in Morbis Acutis*, book ii., usually ascribed to the Cnidian Hippocrates (Aldine ed., p. 159, l. 28). Syennesis is quoted by Aristotle as describing a vein in the right arm under the name *ἡπατῆτις*, which later writers have supposed to be the inner cubital vein of the right arm, and another called *σπληνῆτις*, supposed to be the corresponding vein of the left arm; but there can be little doubt that the "phleps hepatitis" of Hippocrates (*de Ossium Natura*, iii., ed. Foës. 276, 20) is the inferior vena cava, and the "phleps splenitis" of the same author (*De Morbo Sacro*, 304-24) is the splenic vein.

In Galen's treatise, *de Anatomicis Administrationibus*, book 3, there is a minute description of the veins of the arm, which occupies three pages (143-145) in the first Basel edition. This account, though perhaps unrivalled in verbosity, is yet poor in nomenclature, as there are only four of these vessels to which the author has given what may be considered as distinctive

names. The outermost vein is the φλέψ ὤμιαία; the deep axillary vein is named ἡ διὰ τῆς μασχάλης φερούμένη φλέψ, and this gives off a superficial branch, φλέψ μεγάλη that runs on the inner side of the arm to the elbow. A branch of this joins with one of the outer veins in front of the elbow κατωτέρω τοῦπίπαν τῆς μέσης χώρας τοῦ μήκους αὐτοῦ. In the treatise on the dissection of veins and arteries, he again mentions this last vein in the middle of the arm. Corresponding names are given by the other Greek writers in their references to venesection—Paulus Ægineta, Aetius, Oribasius, Actuarius, etc.—none of whom, except the last, add anything to Galen's description. (See Actuarius, *de methodo medendi*, lib. iii.)

When we turn to the anatomical writers of the sixteenth century we find that the majority of them have adopted the nomenclature with which we are now familiar. Realde Columbus (Bevilacqua's Venice ed., 1559, book vi. p. 167) speaks of the "vena humeralis vel cephalica et capitalis dicta," and also of the vena basilica and the vena communis, formed by the junction of branches of these. Of the branches to the fingers, he especially refers to that between the minimus and annularis, and says of it, "hanc venam tum Arabes, tum qui praxim exercent fere omnis salvatellam nuncupant, cujus sectionem in affectibus lienis mire aiunt prodesse."

Riolan also speaks of the cephalica, basilica, and mediana (1611 ed., p. 511), and says that the Arabs have placed their salvatella between the little and ring fingers. This vein the Arabians recommended to open in cases of melancholia, but he quotes Aretæus (*de Morb. Acut.*, lib. 2, c. 2) as saying that this is useless; incidentally, an evidence that the practice must have been much older than the Arabians. Riolan, with characteristic inaccuracy, quotes Alexander Trallianus in this connection as referring to the salvatella by name; but while that author speaks of opening the vein, he simply calls it the vein beside the little finger. (Basel ed., 1556, p. 485.) Riolan further adds that the inner vein of the right arm is the basilic, while that of the left arm is the vena lienalis.

In a later work, Blancard's *Lexicon Medicum* (ed. 1690, p. 80), under the name 'basilica,' we find "basilica hepatica dicta, ἡ βασιλείω, 'rego.'"; to which Kuhn, the editor of the 1821

edition (i. 214), adds, "quia hepar princeps organon sanguificationis, a veteribus aestimatum fuit."

When we turn to Vesalius (ed. Basel, 1543, lib. iii. p. 272), we find that, after carefully describing these veins, he refers to those names which have been given to them by the Arabians, or their translators, and enumerates these names: cephalica, funis brachii (the superficial radial vein of modern authors), asellaris or axillaris, communis or nigra (the vein now called median), and basilica. To the Y-like junction of veins from the annularis and index he gives the name 'syele,' noting, however, that some give that name or the names "salvatellam et salubrem" to the junction lying internal to this, while some apply the name to an outer union.

There seems to have been much confusion as to which was the proper salvatella, doubtless arising from the inconstancy and irregularity of arrangement which characterises these veins. At a later date Bauhin (*Theatrum Anatomicum*, 1621), after giving the then current names, says, "mediana exterior surculum ad carpi sedem anteriorem pollicis versus mittit et cum aliis commisceretur reliquum versus pollicis et indices regionem exporrigitur quam alii salvatellam communiter, tamen a chirurgis cephalica, ab aliis oclularia dicitur. Alter vero interior inter indicem et medium et aliquovisque annularis sedem in varios surculos absumitur et a quibus syele Avicennæ censetur.

From these and other testimonies we learn that the names in use, cephalic, basilic, and median, were taken by the anatomists of the renaissance from their principal medical text-book—the translations of the Canon of Avicenna. This was rendered into Latin by Gerard of Carmona about A.D. 1440.¹ In book 1, fen (= part) 1, doctrina 5, summa 5, chapter 4, the veins are described under the names cephalic, basilic, and nigra. In the Arabic original these names are الكفالى al-kifal, الباسليق al-bāsīlīk, and الأكفال al-akḥāl. Taking these references as final, Professor Hyrtl (*Das Arabische und Hebraische in der*

¹ The translator of the Canon was not a monk, as Hyrtl says (p. 77), but was a Spanish physician, Gerardus of Carmona, who made the translation in Toledo, and died about 1461. Although called Gerardus Cremonensis in the 1507 edition, he is not to be confounded with Sablonata, often called Gerardus Cremonensis, who also wrote on medical subjects, and died about the middle of the fifteenth century.

Anatomie, p. 77) comes to the conclusion that "basilica als blutader ist und bleibt demnach ein Wort arabisches Ursprungs und hat mit König (βασιλεύς) nichts zu schaffen"; and again, at p. 97, "Diesen Kefal bleibt das griechische κεφαλή ganzlich fremd."

These etymologies are adopted in the last edition of "Quain," vol. ii. part 2, where, in the glossary, there is the additional statement, not warranted by Hyrtl, that *al-bāsīlik* means the inner vein. But are these really Arabic words? Their form cannot fail to rouse grave suspicions, and on this subject I asked the opinion of the Lord Almoner's Professor of Arabic, Professor Bevan, who writes concerning them, "I doubt whether they were ever in use among the Arabs, that is to say, whether they occur anywhere except in translations."

Searching for them in the Arabic Lexicons, I find that they are given, at least *al-kīfal* and *al-bāsīlik* (concerning *al-akhāl*, it means simply the black vein), but in neither case are there given any cognate words, and in the case of *al-bāsīlik* it is scarcely possible to imagine a Semitic root of which it could be a derivative.

As we learn from the biographers of the Arabian physicians in general, and Abu Ali el Hosein Ibn Abdalla Ibn Sina in particular, that they derived for the most part their knowledge of the Greek medical writings from Nestorian and other Syriac translations, the next step in the research was to see whether these words could be found in a Syriac form; an easy task, as Payne Smith's *Thesaurus* is practically exhaustive. There *basilikon* is given as the name of the vein, but side by side with it the only cognate words are such as *basilis*, *basilika*, which have the sense of royal, *basilikon*, "medicamentum regale," and one or two other similar words taken from the Lexicons of Jesus Bar-Alli and Jesus Bar-Bahlul. Syriac therefore only knows this word as a loan from Greek. In the cognate language, Hebrew *basiliké* occurs in several places, *e.g.* in the Talmudic tract *Succah*, 51a, also *basilion* in *Peah* 20b, in both places meaning belonging to a king. In *Bereschith Rabbah*, on Gen. 45, 8, the word *Lab* is explained as לַפְסֵן בַּסְלִין = "in patronum regium," and *Midrash Tillim* on Ps. 105 has *basiliké* in the sense of a palace. The conclusion is obvious. In the two

older literary Semitic languages 'basilikon' is borrowed from the Greek, and the presumption is overwhelmingly in favour of its being similarly borrowed in those Arabic texts of which we know that the substance was originally derived from the works of the Greek physicians.

In the case of *Al-kīfal* the history is identical. It occurs in no Arabic text known to me except those of two medical writers, and it has no obvious Arabic etymology. In Syriac, although none of the lexicographers whom I have consulted give it as the name of a vein, yet I find *kephaleon*, in the sense of head, in the *Carmina* of Bar-Hebræus, and several compounds of the same word occur in Jesus Bar-Alīi, and elsewhere, referring to the chapters of books, the capitals of columns, the heads of onion-like plants, all simple loan-words from Greek. In Hebrew, *kēphalos* occurs as the capital of a column in *Aruch*, *kēphalit'a* and similar words, with the central sense of head, in the Talmud (*Sabbath*, c. 6) and other ancient writings. In spite, then, of the emphatic statement of Hyrtl, 'basilic' and 'cephalic' are nothing but the Greek words which have been adopted by the Arabians, and transmitted by them to us. Indeed, in the case of *al-kīfal*, the writer credited with its authorship betrays the source from which he has taken it, as in the *Al-manzūmah fi-l-ttibb*, part iv. line 4 Avicenna says of this vein, it is to be opened in severe pain in the head and in bleeding from the nose, the same recommendation as that given by Paulus Ægineta, vi. c. 40. This treatise was translated under the Latin name *Canticum Avicennæ* by Armegand Blasius of Montpellier, and this passage will be found on p. 513 of Paganini's Venice edition of 1507.

The next question is, as these names are simply transliterated Greek words, from what original source are they derived?

Among the apocryphal works attributed to Galen is one of considerable importance, the treatise *de Anatomia Vivorum*. It only exists at present in its Latin form, and is obviously of later than Galenical date. It is printed in the Junta Venice edition of 1625, and on p. 55H there begins a section on the veins of the hand, beginning thus: "venæ autem manus quæ phleboto-
mantur sunt quinque :: nigra, sive purpurea, basilica, funis
brachii, et axillaris quæ est ramus basilicæ et sceile et cephalica

qui omnibus major est." If we knew the history of this treatise it might establish another stage in the genealogy of these words.¹ It does not itself profess to be Galenical, as Galen is quoted in it : some of these quotations, however, are not from extant works, so there must probably be an original Galenical nucleus, on which the rest is commentary. In two places, Isaac Israelita Beimiram is quoted ; and as he was born about A.D. 840, this gives a major limit for the age of the present compilation ; and as he translated the works of Galen into Hebrew, this may have been a compilation based on some of these. It must be noticed that there is evidence that our Latin version is taken from a Syriac source, for not only is there the word 'sceile,' but in a later paragraph, in describing the ischiadic vein, it says, "est a parte sylvestri calcanei." This is the rendering of a Semitic idiom, the translation of the Hebrew or Syriac word for outside or external ; and this phrase, which is not the proper Arabic for 'outside' (which should be *ḥāridsh*), is sometimes used by Arabic writers, adopted from the Syriac texts with which they were familiar. There are, of course, the equivalent terms in Latin, *domi* and *foris*, but the use of the Semitic periphrasis seems to point to a Hebrew or Syriac source for the Latin text. Farther back I have not yet traced these words, but some Greek text must have existed from which the words have come.

There is less difficulty about the history of the name *mediana*. Celsus, when discussing venesection (ii. c. 10), says, "incidenda ad medium vena est ; ex qua cum sanguis erumpit, colorem ejus habitumque oportet attendere. Nam si is crassus et niger est vitiosus est ; adeoque utiliter effunditur." Here we see the source not only of the name 'mediana,' but also of the name given to it by Avicenna, *al-akhal*, "the black vein." Concerning this vessel, Vesalius, who calls it *vena communis*, says, "Vulgus tamen medianam vocat etiamsi Græce et Latinorum præcipui ramos qui hanc communem efformant medias et obliquas nuncupaverint." We have already noted that Galen likewise speaks

¹ Galen refers to a work of his own on the anatomy of the living, which may be the nucleus of this treatise. Kühn refers, under this head, to a MS. in the library of Peterhouse, Cambridge, but that is only a short abstract, made by some fifteenth century scribe, of anatomical notes culled from the *De Administrationibus*, and has nothing to do with the *Anatomia Vivorum*. I have not seen the Merton College MS.

of the vein in the middle of the arm. Hyrtl, in trying to establish his Arabic hypothesis, was bound to find a similar origin for this word; and the steps by which he arrived at the bizarre etymology given by him (*op. cit.*, pp. 171, 295), and copied into Quain's glossary, were as follows. Blasius, in the translation of the Canticum, speaks of the vein called almerina, which is to be opened in diseases of the spleen and liver. In the 1564 Venice edition there is given the marginal gloss, al-madian. This is clearly, as Hyrtl at first supposed, just another example of word-borrowing, for 'al-madian' is simply 'the median'; indeed, the name almerina is a mistake in transliteration for this word, the confusion of المرين with المدين. Hyrtl, however, wishing to establish an Arabic source, makes the gratuitous hypothesis that this vein is called after Madjan ibn Abderrahman, who wrote a commentary on this work, and that it is the Vein of Madjan! There is not a particle of evidence in favour of this. As well might we say that the Vena portæ was named after the mediæval magician and physiognomist, Giovanni Battista Porta. Eponymous nomenclature was much rarer among the Arabians than it is among us at the present day.

A. M.

ANATOMICAL NOTES AND QUERIES.

9. THE NORMAL TIBIA has been studied by Dr Ales Hrdlicka, and the results of the examination of 2000 bones are summarised in the *American Anthropologist* (Oct. 1898, p. 307). The average lengths he finds to be as follows:—Male right, 36·45 cm.; male left, 36·48; female right, 34·5; female left, 34·6. The extremes are: males, 31 and 45·5; females, 28 and 39.

He recognises six types of sectional forms:—1, prismatic with a right postero-external angle; 2, prismatic with obtuse postero-external angle; 3, with the outer surface concave; 4, quadrilateral; 5, with indistinct inner border; 6, oval. Other measurements and details are carefully given.

10. LITERATURE.—The following papers on Osteology have come under my notice during the last quarter, and deserve the attention of descriptive Anatomists:—

LENGNICK on the Os Kerckringii, *Königsberg Dissertation*, 1898.

LIVINI on variations in the Nasal Bone, *Monitore Zool. Ital.*, ix. No. 5.

TENCHINI on a variety of the Atlas, *Archiv. di Psichiat. Sc. pen. e. Antrop. criminale*, xix. p. 279.

BROMAN, I., on the development of the Auditory Ossicles in Man, *Verhandl. Anat. Gesellsch.*, xii. p. 230.

FAWCETT on the Articulations of the 5th and 6th Rib Cartilages, *Anat. Anzeiger*, xv. p. 30; and

BARDELEBEN on the same, *ibid.*, p. 82.

HANS VIRCHOW on the Skeleton of the Extended Hand, *Verhandl. der Berliner Gesellsch. f. Anthropol.*, 1898, p. 129.

The anatomical peculiarities of the mastoid region in infants, as viewed from the standpoint of operative surgery, are pointed out very clearly by Dr Harold Stiles in the *Brit. Med. Jour.* for Oct. 15, 1898, p. 1141.

11. OCCIPITAL CENTRES OF OSSIFICATION.—In two foetal skulls in the Cambridge Collection there are additional centres of ossifica-

tion in the interval between the hinder border of the exoccipital and the contiguous edge of the occipitale superius, that is, in the cartilaginous part of the occipital. In one this is a single centre to the left of the middle line, not in the margin of the foramen magnum, but well to the left of it. It is a quadrilateral ossicle, measuring 6 cm. by 4. In the second instance there are three ossicles in the supra-exoccipital interval, one on either side at the hindmost border of the exoccipital, and one on the right of the middle line between the postero-interior border of the exoccipital and the neighbouring edge of the supra-occipital, bordering medially on an os Kerekringii, which has become united to the supra-occipital. This is in size 10 mm. by 8.

In a third specimen a very small bony speck occupies this place, and coexists with a well developed os Kerekringii.

I have not had time to look up the literature of the subject, but I do not find any allusion to this in Stieda's paper (*Anat. Hefte*, ii. 59) or in Hagen's or Lucy's monographs. I shall be glad to receive any information about these.

12. LITERATURE OF MUSCLES AND LIGAMENTS.—The following papers on Syndesmology and Myology are noteworthy:—

HAGOPOFF on the origin and mode of development of the Capsular and Round Ligaments of the Hip-Joint, *Comptes Rendus Soc. Biol. Paris*, series x. p. 41.

AUVRAY on anomalies of the Coraco-brachialis and other Muscles, *Bull. Soc. Anat. Paris*, 1898, p. 136 and p. 146.

PASTEAU, the Tibial Groove for the Popliteus Muscle, *ibid.*, p. 137.

KOHLBRUGGE, the homology of Neck and Trunk (dealing especially with Muscles and Nerves, *Archiv f. Anat. u. Phys. Anat. Abth.*, 1898, p. 199.

MAILLARD, the Humeral Extension of the Lesser Pectoral Tendon, *Bibliographie Anatomique*, vi. p. 36.

BOLK on the Short Head of the Biceps Femoris in the Orang, a specimen supporting Kohlbrugge's theory that this is genetically related to the peronei, *Morph. Jahrb.*, 1898, p. 274.

COUSIN, fascial relations of the Omohyoid Muscle, *Bull. Soc. Anat. Paris*, 1898, p. 334.

13. THE BILATERAL ACTION OF THE LATISSIMUS DORSI.—Dr Beevor (*Brit. Med. Jour.*, Oct. 1, 1898, p. 977) has made some most suggestive observations on the respiratory action of this muscle. He notices that in coughing the latissimus contracts

on both sides, as can be felt by placing the finger and thumb on the muscle at the posterior border of the axilla of a person who is coughing. As the latissimus acts slightly as a muscle of inspiration, this doubleness of function is remarkable, but he suggests that probably the iliac and lumbar fascial part is that which contracts in the former case, and the costal fibres in the latter.

Out of twelve cases of hemiplegia in which the unilateral voluntary power of adducting the humerus was lost, the expiratory function persisted in ten, so that a lesion of the motor cortex or of the internal capsule may paralyse the opposite latissimus as a unilateral limb-muscle, but will not paralyse it when it acts as a bilateral muscle of respiration.

Dr Beevor's explanation of this phenomenon is ingenious. He considers that for the upper limb movement, the latissimus dorsi of one side must be represented unilaterally in the cortex cerebri of the opposite side; and that for the respiratory movements, both muscles must be represented in the cortex of each side, but that each muscle is represented more in the cortex of the opposite side; so that in a lesion of the cortex or of the internal capsule of one side, the unilateral action for the opposite upper limb, which is represented in that cortex, will be paralysed, but the bilateral respiratory movements, which are also represented in the intact opposite cortex, will be retained.

As a means of diagnosis, this differentiation is of great importance in separating cerebral lesions from those of the spinal cord and peripheral nerves, and it would be of special value in cases where the arm and leg of one side are involved without the face.

14. SOME RECENT PAPERS ON DESCRIPTIVE NEUROLOGY:—

LANGLEY, union of Cranial Visceral Fibres with Nerve-cells of the Superior Cervical Ganglion, *Journal of Physiol.*, xxiii. p. 240.

KOHNSTAMM on the Nucleus phrenicus, *Fortschritte der Medicin*, xvi. 643.

LAPIQUE, relation of Brain Weight to Body Weight, *Comptes Rend. Soc. Biol. Paris*, v. 62.

BOURNEVILLE on the unequal Weight of the Cerebral Hemispheres, *Progrès Medical*, 1898, p. 248.

LAFFAY, an anomaly of the Lacrymal Nerve, *Gaz. des hôpitaux de Toulouse*, 1898, p. 82.

MANOUVRIER on the proportions of the Cerebral Lobes and their Craniological consequences, *Bull. Soc. Anthropol. de Paris*, 1897, p. 559.

ADOLPHI on the relation of the 2nd Thoracic Nerve to the Brachial Plexus, *Anat. Anzeig.*, xv. 98.

TONKOFF, a case in which the Dorsal Cutaneous Branches of the Musculo-spiral replaced the Radial Nerve in the Supply of the Back of the Hand, *Internat. Jour. of Anat.*, xv. 156.

BILLARD and CAVALIE on the function of the Diaphragmatic Branches of the Intercostal Nerves, *Comptes Rendus Soc. Biol. Paris*, v. 306.

15. THE NEURONE DOCTRINE.—This important theme, indirectly anatomical, is treated by Dr Lewellys F. Barker in the *American Journal of Insanity*, lv. 31; and the author comes to the conclusion "that the control instituted by hundreds of histologists in various parts of the world has gone to confirm the conception that the neurone is a unit in the sense of Waldeyer."

16. Apropos of Tonkoff's case referred to above, I have just seen an anomalous distribution of the corresponding nerves in the leg, of which I know not any other example in the literature of anomalous neurology. The peroneal having given off (1) a large *communicans peroneus* (ultimately distributed, after uniting with the *c. tibialis*, to the fibular side of the 2nd, the 3rd, 4th and 5th toes on the dorsum of the foot), and (2) a posterior cutaneous branch, breaks up into a network of branches distributed to the muscles of the anterior tibial and peroneal region, but sends no branch along with the anterior tibial artery, nor is there any *peroneus superficialis*. The extensor brevis digitorum has no belly for the hallux nor for the 2nd toe, and the two bellies which are present (for the 3rd and 4th toes) are supplied by a branch of *communicans fibularis*. The 1st and part of the 2nd toe were wholly supplied on their dorsal aspect by the long saphenous. I shall be glad to get references to any similar cases.

17. SOME RECENT PAPERS ON VISCERAL ANATOMY:—

LETULLE and NALTAN LARRIER on the Vaterian Region of the Duodenum, *Bull. Soc. Anat. Paris*, 1898, p. 491.

MOUCHET, a Liver with Rudimental Left Lobe, *ibid.*, p. 201.

BARNSBY, the Appendiculo-ovarian Ligament, *ibid.*, p. 138.

BRIAN, E., the Innervation of the Thyroid Body, *Lyons Thesis*, 1897.

GLAUTENAY and GOSSET, the Perirenal Fascia, *Annales des Malad. Génit. Urin.*, xvi. p. 113.

MOYNIHAN on the double nature of the Duodeno-jejunal Fossa, and its Para-duodenal and Inferior-duodenal Components, *Brit. Med. Jour.*, Nov. 19, 1898, p. 1587.

STOPNITZKI on the arrangement of the Loops of Small Intestine and of the Jejuno-iliac Mesentery, *Internat. Jour. of Anat.*, xv. p. 219.

CHARPY on the capacity of the Cæcum, *Bibliograph. Anat.*, vi. p. 143.

ROHAN on the position of the Transverse Colon, *Paris Thesis*, 1898.

HELLY on the Anatomy of the Pancreas and its Duct, *Arch. f. Mikrosk. Anat.*, lii. p. 773.

MÜLLER, the position of the Duodenum in the Fœtus, and the general Topography of the Fœtal Abdominal Organs, *Kongl.-Svenska Vet. Akad., Handl.* xxix. p. 2.

BIELKA VON KARLTREN, a double Kidney on the Left Side, *Arch. f. Path. Anat.*, clii. p. 545.

BETTMANN, the shape of the Stomach, *Amer. Jour. of Med. Sci.*, cxv. p. 428.

RABL, the Histology of the Ovary, Merkel and Bonnet's *Anat. Hefte*, xi. heft 2.

HIRSCHLAND, the development of the Mammary Organ in the Human Subject, *ibid.*, p. 221.

STRAHL, the development of the Mammary Organ, *Verhandl. Anat. Gesellsch.*, xii. p. 236.

KIRCHNER on the position of the Nipple and the relation of the Apex of the Heart to the Left Nipple Line, Merkel and Bonnet's *Anat. Hefte*, x. heft 3.

KALLIUS, development of the Human Larynx, *Verhandl. Anat. Gesellsch.*, xii. p. 240.

HENKE, anomalies of the Uvula, *Monatsch. für Ohrenheilk., etc.*, xxxii. p. 318.

GOLDBERG on double Uterus, *Freiburg Dissertation*, 1897.

DRURY, a bicuspid Aortic Opening, *Brit. Med. Journ.*, 1898, p. 1689.

18. THE SURGICAL ANATOMY OF THE LYMPHATIC GLAND.—Dr Leaf's admirably illustrated work, recently published by Archibald Constable & Co., is a valuable contribution to surgical anatomy, and gives abundant evidence of painstaking investigation. The suggestion that students should habitually dissect the lymphatic glands and their connexions is scarcely practicable, and would add considerably to their difficulties. The author does not give any evidence for his positive statement,

that infection of the supraclavicular glands in mammary scirrhus shows that the thorax and pectoral muscles are involved. The author's suggested operation for the removal of cervical glands is, *prima facie*, a useful modification of the ordinary procedure.

H. HIGGINS.

19. THORACIC DUCT SURGERY AND LYMPHATIC AND LACTEAL ANASTOMOSES.—The existence of these is assumed in the report of a case of suture of a wound of the duct by Dr H. Cushing (*Annals of Surgery*, June 1898). One has so few opportunities of examining injected lacteals or lymphatics, that our knowledge of the course whereby the chyle could get into the right thoracic duct in case of ligature of the left is at any rate imperfect. A critical study of the cross-lymph channels in the thorax would be interesting in this connexion.

20. ANOMALIES OF THE KIDNEYS.—Two cases of displaced kidneys are described by Dr C. P. White, Demonstrator of Pathology at Leeds, in the *Lancet* for November 5th. In neither case, however, is there any reference to the peritoneal relationship. It is of importance that this should be noted in such cases, as bearing on the morbid anatomy of movable kidney. In the same paper are noted some other anomalies, one of the most interesting of which is a developed diverticulum Vateri.

21. MEASUREMENTS.

21. MEASUREMENTS OF THE MALE NEGRO.¹—The following are the measurements [in millimetres] of a young male negro, received at the Cambridge Anatomy School, October 27, 1898:—

Stature—vertex to heel, . . .	1694	Face—supra-orbital margins to chin, . . .	125
Vertex to tip of coccyx, . . .	811	„ maximum bizygomatic breadth, . . .	122
Vertex to umbilicus, . . .	648	„ external biorbital breadth, . . .	124
Vertex to tuber ischii—sitting height, . . .	856	Ear—height, 62 R., 63 L. breadth, 38 R., 41 L.	
Umbilicus to heel, . . .	1050	Circumference of thorax, max., . . .	900
Umbilicus to upper surface symphysis pubis, . . .	136	„ of abdomen, . . .	882
Height of symphysis pubis, . . .	40a	„ of arm, . . .	312
Span of arms, . . .	1654	„ of forearm, . . .	292
Upper extremity—total length, . . .	768	„ of thigh, . . .	448
Upper arm, . . .	301	„ of leg, . . .	367
Forearm, . . .	238	„ of pollex, . . .	74
Ulna, . . .	260?	„ of hallux, . . .	87
Breadth of palm, . . .	94	(These circumferences are only approximative, being so much influenced by condition of limb.)	
Length of pollex, . . .	68	Mouth—angle to angle, . . .	45
„ index, . . .	74	Eye—rictus, . . .	30
„ medius, . . .	77	„ inter-orbital breadth, . . .	33
„ annularis, . . .	69	Nose—height, . . .	49
„ minimus, . . .	55	„ width, . . .	43
Upper margin symphysis pubis to heel, . . .	892	Circumference of head, . . .	562
Anterior superior spine to adductor tubercle, . . .	454	Breadth of head, . . .	120
Head of femur to adductor tubercle, . . .	?	Length of head, . . .	151
Length of thigh, . . .	454	Extreme breadth of sole of foot, . . .	90
„ leg, . . .	415	Breadth index of head, . . .	79.4
„ pes, . . .	217	„ of skull, prob., . . .	77.4
„ hallux, . . .	47	Nasal index—soft parts, . . .	877
„ 2nd, . . .	37	Aural index—61.3, and L. . .	65
„ 3rd, . . .	29		
„ 4th, . . .	26		
„ 5th, . . .	23		

¹ Owing to the generally oedematous condition of the limbs, some of the measurements proved very difficult to take with accuracy. There was a curious appearance of mottling about the front of the tibiae, with indistinct cicatrices, due probably to the subject having been employed at some time or other as a stoker.

W. H. L. DUCKWORTH.

22. RECENT PAPERS ON PHYSICAL ANTHROPOLOGY:—

Brunswick Skulls—*Beiträge zur Anthropol. Braunschweigs Festschrift*, 1898, p. 107.

Elsass Skulls—BLIND, in *Beitr. z. Anthropol. Elsass-Lothr.*, part i., 1898.

Norwegian Skulls—ARBO, in *Globus*, lxxiii. p. 117.

Hawaiian Skulls—ALLEN, in *Trans. Wagner Free Inst. of Sc.*, Philadelphia, v., 1898.

Swiss Skulls from Valais—*Rev. Mensuel de l'École d'Anthropol.*, Paris, No. 3, p. 86.

African Skulls—SHRUBSALL, in *Journal Anthropol. Inst.*, N.S., part i., 1898.

23. ON ANATOMICAL NOMENCLATURE, there is an important paper by Prof. Gegenbaur in the last part of the *Morph. Jahrb.* (1898), in which there is reprinted a memoir by the late Geheimrath Schultze of Greifswald on the endings -ides and -ideus of Greek names.

24. ON ANATOMICAL TECHNIC.—Grönroos' paper on the methods in use for the preservation of subjects in the various European laboratories is worthy of careful perusal, although it does not represent adequately the various methods in use in Great Britain and Ireland. (*Anat. Anzeiger*, xv. p. 61.)

25. SUPRA-CONDYLOID PROCESS IN THE CHILD. With reference to the very important query which appeared in the last number of this *Journal*, I may mention that for some years I have had in



my possession a pair of humeri taken from a male child of three years old, each of which presents a well marked and completely ossified supra-condyloid process. These bones measure 145 mm. in length. In the left humerus the process is 4 mm., and in the right 3 mm. This session, however, I have been so fortunate as to obtain from the Rotunda Hospital a full-time male still-born foetus, which possessed an extremely large supra-condyloid

process on each side. Each humerus measures 96 mm. in length. In both bones the process is 5 mm.; and further, it is fully ossified from base to tip (see fig.). From this it would appear that the supra-condyloid process is ossified along with the diaphysis, and from the same centre; and further, that its ossification is completed at an extremely early date.

D. J. CUNNINGHAM.

The Acting Editor will be much obliged if Authors will send offprints of their papers for notice in the *Journal* to him. Address—Prof. Macalister, Cambridge.

Journal of Anatomy and Physiology.

THE SEXUAL DIFFERENCES OF THE FETAL PELVIS.

By Professor ARTHUR THOMSON, Oxford. (PLATES XIII.-XV.).

THE conflicting statements in many of the standard text-books of midwifery, together with an almost entire absence of any reference to the subject in most anatomical works, led me to make a series of observations on the pelvis, with the object of determining whether or no there were any sexual differences which could be recognised during fetal life. At this time I was ignorant of Fehling's work on the subject, and unfortunately I have not been able to obtain access to his original papers, having to content myself meanwhile with abstracts from different sources. This, perhaps, is not an unmixed evil, for my results, obtained independently, strikingly confirm what I assume is Fehling's main contention, that the differences in form and appearances are such as to enable the observer to discriminate between the pelvis of the male and female as early as the third month of foetal life. To Fehling,¹ therefore, belongs the credit of having first pointed out this remarkable fact, a fact which seems to have met with but scant recognition by both anatomists and gynaecologists. In a work published so recently as 1888,² it is stated that "There is, however, nothing which would enable us to distinguish with even an approach to certainty between the male and female pelvis until the period of puberty"; and in the more recent American text-book³ (1896) the follow-

¹ "Die Form des Beckens beim Fötus u. Neugeborenen," *Beiträge zur Geburtshilfe* *auth. fi*
Gynäk., Bd. ~~ix~~ ^{x.} 1876

² *System of Midwifery*, Leishman.

³ *Text-book of Obstetrics*, Norris, 1896.

ing passage occurs:—"The distinctive characteristics of sex are acquired after puberty, although, according to Fehling, indications of these peculiarities are present even at birth,"—a very half-hearted recognition of the facts.

Schauta,¹ whilst referring to Fehling and Litzmann's² observations, scarcely credits them with the importance which they deserve. Nor do we get much more information from the anatomists. Quain passes it by without reference. Macalister, the only English anatomist, so far as I know, who mentions it, is satisfied with a brief note to the effect that "These sex characters are discernible even at birth"; whilst Humphry states that "It is not till after puberty that the distinctive peculiarities of the male and female pelvis, particularly the preponderance of the transverse diameter, are recognised."

Testut and Poirier ignore the subject, the latter contenting himself with a reference to Fehling's work on the obliquity of the foetal pelvis.

In view of this state of things, it is not surprising that gynæcologists and others interested in the mechanism of the female pelvis have been at great pains to account for its peculiarity of growth. The mechanical effects of pressure and the influence of posture and muscular action have been the favourite explanations; and whilst willing to admit that any or all of these may exercise an important influence on the form of the adult as compared with the foetal pelvis, it is difficult to see how the same forces are to lead to different results in the two sexes. Matthews Duncan,³ whose views on the development of the pelvis have met with wide acceptance, evidently felt this, for in accounting for the fact that the male pelvis does not respond to the same forces in a similar way to the female, he puts forward the somewhat unsatisfactory suggestion that "The changes are less marked, for in it (the masculine pelvis) the bones are thicker and stronger and stouter, and earlier consolidated with each other. These conditions are at once the signs and causes of the peculiarities of a masculine pelvis." Hermann Meyer⁴

¹ Müller's *Handbuch der Geburtshilfe*.

² *Die Formen des Beckens*, 1861.

³ *Researches in Obstetrics*.

⁴ *Lehrbuch der Physiologischen Anatomie*.

also seemed to regard some explanation of this difference necessary, for he assumed that during growth the female pelvis is more plastic than the male.

The purpose of this paper is, however, not to discuss the influences to which the pelvis may be subjected after birth, but rather to emphasise the fact already pointed out by Fehling, that at a comparatively early period in the development of the foetus the *sexual* differences are as pronounced and characteristic as they are in the adult. If this can be proved, the explanations, however ingenious, hitherto advanced, become needless and unnecessary, the factors which determine the subsequent growth of the pelvis exercising their influences on male and female alike.

For the sake of comparison, it may be well to tabulate the differences generally recognised between the male and female pelvis under the heading—

1. The pelvis as a whole: its relative proportions in height, width, and the slope of its walls.
2. The false pelvis. The form and mode of expansion of the iliac fossæ.
3. The true pelvis:
 - (a) Its form and diameters, particularly the inlet.
 - (b) The sacrum.
 - (c) The ischium; projection of ischial spines.
 - (d) The pubes; body, and angle of pubic arch.
 - (e) The great sacro-sciatic notch.

besides some minor points, which will be dealt with subsequently in the text.

Before proceeding to discuss these points in detail, it is advisable to say something regarding the specimens on which these observations are based, and at the same time to point out some of the obvious sources of error which have led to wrong conclusions in the past. The pelves for the present inquiry were taken from foetuses which had been previously hardened in spirit or formalin. After being carefully cleaned and prepared by my Assistant, Mr Chas. Robertson, it was found that they retained their form sufficiently well for all practical purposes, the coccyx alone excepted. This, however, was a matter of little moment, and does not invalidate any of the results

obtained. The specimens have all been conserved as wet preparations, and the measurements made, and the photographs obtained, have been taken from the moist specimens. This is a matter of great importance, as the conclusions arrived at from the examination of dried specimens are absolutely fallacious, the shrinkage of the cartilage and the drying and contraction of the ligaments having produced distortion to such an extent as to render worthless any conclusions based upon them. It is necessary to emphasise this, as Galabin,¹ in criticising Fehling's conclusions, says, "but almost all foetal pelves do show in some degree characters corresponding to the change enumerated above, and it is impossible that any changes in drying should always occur in the same direction." As a matter of fact, this is precisely what does happen, so that it is well to guard against such a source of error.

The measurements taken were those selected by Sir William Turner in his "Challenger" Monograph, but it was felt that in dealing with structures of so small a size, the relative proportions and angles could be but roughly estimated, the difference of a millimetre in the foetal condition corresponding with a much larger difference in the adult. Besides the difficulty of estimating measurements so small, it was felt that the results obtained hardly conveyed the differences in form and size which were apparent to the eye. For this reason it was decided to adopt a graphic method of comparison, which would enable the reader to estimate for himself the characteristics of the pelves of either sex. The results obtained must speak for themselves. In order, however, to render clearer some of the more important features, diagrams have been carefully prepared by the enlargement of the original negatives, and the results are represented in schematic form. In taking the photographs, a lens of long focus and narrow angle was employed, so as to reduce as far as possible the distortion resulting from forced perspective. In this respect, therefore, the photographs approach, as near as can be, orthographic representations.

Taking first the proportions of the pelvis as a whole (see table), it will be seen that the breadth-height index is high, viz., 85.6 for the females and 82.4 for the males; in other words, this

¹ *A Manual of Midwifery*, London, 1891, p. 28.

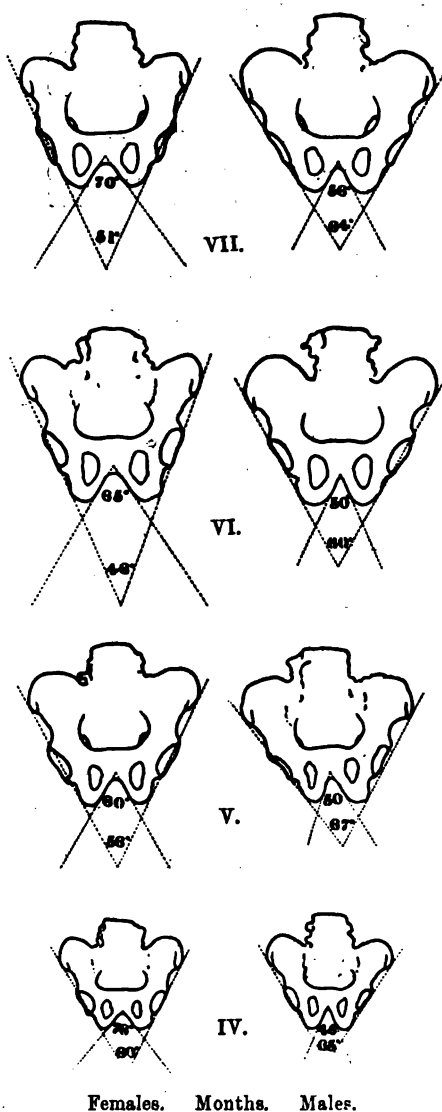
	About vii. months.		About vi. months.		About v. months.		About iv. months.		Average.	
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.
Breadth of Pelvis, . . .	66	58	53	51	49	48	36.5	35	51.1	48
Height of Pelvis, . . .	53.5	49	45.5	44	39	41.5	30	30	42	41
Breadth—Height Index, . . .	81.1	84.4	85.8	86.2	79.5	86.4	83.3	85.7	82.4	85.6
Breadth between Ant. Sup. Iliac Spines, . . .	61	55	50.5	47.5	45.5	45	35	32	48	44.8
Breadth between Post. Sup. Iliac Spines, . . .	19	19	13	13	12	15	9.5	10.5	13.3	14.3
Breadth between Ischial Tuberosities, . . .	25	26.5	22	22.5	18	19	13	15	19.5	20.7
Breadth between Ischial Spines, . . .	19	19	11.5	17.5	9.5	11	8	8.5	12	14
Greatest diameter of Cotyloid Cavity, . . .	12.5	11	11	10	8	9.5	5.5	5.5	9.2	9
Vertical diameter of Obturator Foramen, . . .	12.5	11	10	8.5	8.5	8.5	5.5	5	9.1	8.2
Transverse diameter of Obturator Foramen, . . .	11	10.5	9.5	10	6.5	7	5.5	4.5	8.1	8
Sub-pubic Angle, . . .	7.5	8	6.5	6	5	5	4	3	8.7	5.5
Brim, Transverse Diameter, . . .	56°	70°	50°	65°	50°	60°	46°	76°	50.5°	67.7°
Brim, Conjugate, . . .	28	27	23	21.5	19.5	20	14.5	15	21.2	20.8
Pelvic or Brim Index, . . .	23	23	17.5	19	16.5	17	14	11	17.7	17.5
Brim, Oblique diameters, right, . . .	82.1	85	78	90	86.8	85	100	73	86.2	83.2
Brim, Oblique diameters, left, . . .	26	27	21	21	20	20	13.5	15	20.1	20.7
Inferior Sagittal diameter, . . .	26	27	21	21	20	20	13.5	15	20.1	20.7
Coccygeo-pubic diameter, . . .	17	22	18.5	20	17	18.5	15	13.5	16.8	18.5
Intertuberal diameter, . . .	15	17.5	15.5	15.5	15.5	13.5	15	11	15.2	14.3
Depth of Pubic Symphysis, . . .	18.5	20	14.5	19	11	13.5	8	11	18	15.8
Depth of Pelvic Cavity, . . .	10.5	10	10	10	8	8	6	6.5	8.6	8.6
Inter-obturator width, . . .	24.5	23.5	22	21	19	18	14	13	19.8	18.8
Inter-cotyloid width, . . .	10	10	6.5	8	7	7	5	6	7.1	7.7
Width between Ant. Inf. Iliac Spines, . . .	34	33.5	25.5	27	22.5	22	17	15	24.7	24.3
Ilium—	47.5	44.5	38	34.5	32.5	32.5	23	24	35.2	36.3
Height Length, . . .	32	30	27.5	27	23	25.5	19	18.5	25.3	25.2
Breadth, . . .	37	32.5	32	31.5	27	27	21.5	20.5	29.3	27.8
Iliac Index, . . .	115	108	118	115	117	108	113	113	116	111
Breadth of Innominate Bone, . . .	39	37	34.5	33	28	31	22	22	30.8	30.7
Length of Os Pubis, . . .	19.5	18	14.5	14	12.5	13	9	9	13.8	13.5
Pubo-innom. Index, . . .	50	48	42.6	42	44.6	42	40.9	40	44.5	43
Length of Ischium, . . .	17	16	14	14	12	12	8	8	12.7	12.6
Innominate Index, . . .	73.5	75	76.6	75	73.6	75	73.3	73	74.2	74.5
Ischio-innom. Index, . . .	32	32	31.1	31	30.7	29.7	26.6	26.6	30.1	29.8
Length of Sacrum, . . .	25.2	27	22.5	24.5	22.5	21.5	16.5	18	21.6	22.7
Breadth of Sacrum, . . .	29.5	28	22.5	24.5	22.5	21.5	16.5	16.5	22.7	22.6
Sacral Index, . . .	118	103	100	100	100	100	100	96	104	99.7

[In the above table the measurements are given in millimetres.]

means that the height of the foetal pelvis is great in proportion to its width,—the breadth-height index of Europeans averaging about 74 and 79 for females and males respectively. It follows from this that during the growth of the pelvis from the foetal to the adult form there is a greater proportionate growth in width than in height. It will be noted, however, that in the foetal condition the breadth-height index is higher in the female (85·6) than in the male (82·4), the converse of what holds good in the adult, where the breadth-height index (79) exceeds that of the female (74·75), so that it would appear that during growth the female pelvis increases in width more rapidly than in height, a circumstance no doubt associated with the peculiarity of the form and size of the hinder portion of the ilium, to be hereafter referred to. At the same time, it may be pointed out that whilst the proportions between the height and width of the foetal pelvis differ from the corresponding proportion in the adult, it is the case that in the foetal condition the diameters of the male pelvis are absolutely greater than the female. The comparatively small number of specimens I have been able to examine, apart from those figured and measured in this paper, and the difficulty of being sure that the male and female specimens are precisely the same age, renders it advisable not to put too much reliance on these figures.

In the foetus the splay of the lateral walls of the pelvis is greater in the male than in the female. Thus the sides of the male pelvis, as indicated by lines drawn through the points of extreme width of the iliac crests and the ischial tuberosities (see fig. 1), are set at an angle on an average of about 64° , while the sides of the female pelvis are inclined at an angle of about 53° to each other. It is noteworthy that this difference in the splay of the pelvic walls is characteristic of the different sexes in the adult, the female pelvis being frequently described as a short segment of a long cone, as contrasted with the male, which is a long segment of a short cone. This difference in the splay of the sides of the pelvis necessarily reacts on the proportions of the true and the false pelves, whereas in the female, owing to the nearer approach to parallelism in the disposition of the sides of the girdle, the lower segment (*i.e.*, the true pelvis) bears a greater proportion to the upper segment (*i.e.*, the false pelvis); in the male, owing to the greater splay of the pelvic wall as a whole, the proportion

of the lower segment to the upper is much less than in the female. I have been led by my observations to place considerable



Females. Males.

FIG. 1.—Fœtal pelvis.

importance on the proportion of the width of the ilium (taken from the anterior superior to the posterior superior iliac spine) to

the total pelvic height, assuming the latter equal 100. This may be determined in adults from Verneau's¹ figures, as follows:—

Verneau.	Height of Pelvis.	Breadth of Ilium.			
Males, .	220 mm.	: 164 mm.	:: 100	:	74·5
Females,	197 „	: 156 „	:: 100	:	79·1

In the foetal pelvis the proportions are—

Males, .	42 mm.	: 29·3 mm.	:: 100	:	69·7
Females,	41·1 „	: 27·8 „	:: 100	:	67·6

Too much stress must not be laid on these results, as the difficulty of taking the measurements accurately on so small a scale is very considerable; yet the results are sufficient to show that, comparing the foetal pelvis with the adults, the latter have proportionately wider ilia; in other words, this means that during growth the increase in width of the ilium is proportionately greater than the increase in height of the innominate bone. Comparing now the innominate indices, *i.e.*, the proportion of breadth from symphysis pubis to posterior superior iliac spine to the pelvic height, I find that in 5 male, presumably European, pelvis, this index averaged 87·1, whilst in 8 female pelvis, also probably European, the index was 93. Contrasted with this, the foetal innominate indices are for the males 73·3, and 74·6 for the females, thus proving that during growth the increase in width of the innominate bone is proportionately greater than its increase in height.

The capacity of the false pelvis depends upon the form and disposition of the iliac bones. As regards what may be termed the sexual characteristics of this part of the pelvic girdle, there is considerable diversity of opinion, if one may judge from the varied accounts published in the different text-books. Quain, for instance, says: "The ilia are more vertical (in the female), and thus the false pelvis is relatively narrower than in the male. On the other hand, both Testut² and Poirier,³ in describing the dorsal aspect of the ilia (*fosses iliaques externes*), assign to the male a more vertical direction. Galabin⁴ describes the iliac fossæ in the female as more widely spread out, thus giving a

¹ *Le Bassin dans les sexes et dans les races*, Paris, 1875.

² *Traité d'Anatomie humaine*, Paris, 1896.

³ *Ibid.*

⁴ *A Manual of Midwifery*, 1891.

greater breadth across the hips to woman's figure, a statement with which Playfair¹ apparently agrees; whilst Lusk,² in speaking of the characteristics of the female as contrasted with the male, says of the former, "The iliac incline approaches more nearly a vertical line." These extracts from the opinions of recognised authorities are sufficient to demonstrate the somewhat unsatisfactory state of our knowledge. Verneau,³ whose observations are based on numerous and accurate measurements, says that the inclination of the internal iliac fossæ is practically the same in the two sexes, but in the female these hollows are not so high; at the same time, they are more excavated.

A study of the photographs shown on Plate XIV., as well as the diagrams therefrom constructed, will, I trust, demonstrate the fact that there is remarkable uniformity of type in the disposition of this part of the pelvic girdle in the two sexes.

As viewed from above, the male ilia are clearly seen to be more open and expanded, whilst the fore part of the female ilia tends to be inturned; this, together with the lesser splay of the innominate bones in the female already referred to, combines to form a false pelvis, the sides of which are more vertical. Whilst the form of the false pelvis undergoes great individual variations in the two sexes, the reader cannot fail to be struck with the characteristic type displayed in the male and female series of foetal pelves. Further, the curve of the iliac crest reaches a higher level, and is more pronounced in the male than in the female, as happens also in the adult forms (see Plate XV.). I have estimated this difference in the adult in the following way: A line was drawn across the outer side of the ilium from the anterior superior iliac spine to the posterior superior iliac spine; from this line the greatest perpendicular height of the iliac crest was measured, with the result that in four males the distance was found to average 66 mm., as contrasted with 58 mm., the mean of eight females.

✓ It is, however, in the true pelvis that the appearances characteristic of sex are principally met with. These differences are so generally recognised in the adult that it is unnecessary here to dwell upon them, except to point out that in the foetus they are just

¹ *The Science and Practice of Midwifery*, 6th edition.

² *The Science and Art of Midwifery*.

³ *Le Bassin dans les sexes dans les races*, Paris, 1870.

as distinctive. The form of the inlet in the male is described as cordate, as contrasted with the more uniformly oval, elliptical, or reniform aperture in the female; this difference is due to the maximum transverse width in the male being placed in a plane posterior to the greatest transverse diameter in the female. The same characteristic forms are seen in the foetal pelvis here figured, the shapes typical of the two sexes being readily recognisable as early as the fourth month. It has long been assumed, and the assumption has been based, no doubt, on the measurements of dried specimens, that the conjugate exceeded the transverse diameters in the foetal condition. ✓ According to Burns,¹ whose figures have been extensively quoted, it is not till about the tenth year that the transverse diameter exceeds the conjugate. Hennig,² in an elaborate paper on the child's pelvis, has pointed out that such is not the case, and confirms Fehling's observations on the pelvis of the new-born child; yet, despite these researches, there seems to be a strong tendency to cling to the older accounts.

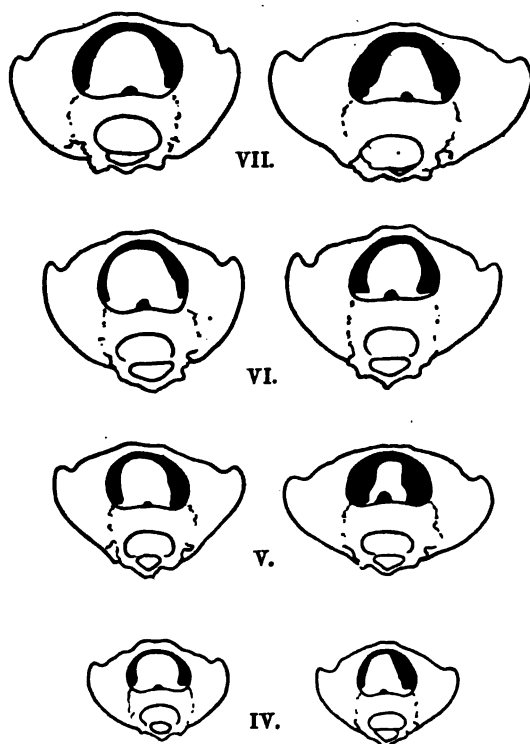
✓ In the four female foetal pelves which I have measured, the average transverse diameter of the brim was found to be 20·8 mm., as compared with an average conjugate of 17·5 mm.; the four males yielded an average of 21·2 mm. for the transverse, and 17·7 for the conjugate diameters. Verneau gives for adult females the following averages: conjugate 106, and transverse 135; males, conjugate 104, transverse 130. Comparing these results, it will be seen that the differences between the conjugate and transverse diameters in the foetal pelves are very nearly proportional to the difference between the same measurements in the adult. ✓ Thus, in order to attain the adult proportions, there need only be an increase in width of 7 mm. in the female and 5 mm. in the male, supposing the foetal proportions are otherwise maintained. The proportions of the conjugate diameters to the transverse in the series of foetal pelves has been estimated by means of the formula suggested by Zaaier and employed by Sir W. Turner, viz.,

$$\frac{\text{Conjugate diameter} \times 100}{\text{Transverse diameter}} = \text{pelvic index.}$$

¹ *Principles of Midwifery.*

² "Das Kindliche Becken," *Archiv für Anat. u. Entwicklungsgeschichte*, 1880.

The results obtained are an index of 83·2 for the females and 86·2 for the males. They are therefore included in the platypellic group, according to Turner's classification. It is remarkable how close the agreement is between the indices of the foetal form and the adult. Quoting from Sir W. Turner's



Females. Months. Males.

FIG. 2.—Fœtal pelves.

monograph,¹ the indices have been estimated as follows by the subjoined authorities:—

	Males.	Females.
J. J. Watt, . . .	87·9	87·3 Pelvic index.
John Wood, . . .	85	86 "
Sir W. Turner, . . .	77	79 "
Verneau, . . .	80	78 "
Gegenbaur . . .	84	85 "
Sir W. H. Flower, . . .	81	78 "

¹ "Report on the Human Crania and other Bones of the Skeleton," *Challenger Reports—Zoology*, vol. xvi.

"In the measurements made by J. Wood, Gegenbaur, and myself (Sir W. Turner), the brim index in the male pelvis is a little below the brim index in the female; but in those measured by J. J. Watt, Verneau, and Flower, the brim index of the males somewhat exceeded the females." In this respect, therefore, the indices of the foetal pelvis are in agreement with the observations of the latter observers, for the male index, 86, exceeds the female index, 83.

✓ The proportion which the sacrum bears to the pelvic inlet, as well as its size in relation to the pelvis as a whole, is a matter of some interest, in view of the statement so often repeated, that the shortness of the transverse diameter of the brim is due to the narrowness of the foetal sacrum.¹ Now, as a matter of fact, the foetal sacrum is larger in proportion to its surroundings than in the adult. When we consider that the sacrum forms part of the axial skeleton, whilst the innominate bones belong to the appendicular skeleton, and are necessarily associated with the development of the lower limbs, this does not appear surprising. ✓ The facts, however, are best ascertained by comparing the proportion of the breadth of the sacrum to the greatest pelvic breadth in both the adult and the foetus, taking Verneau's figures, and comparing the greatest width between the iliac crests with the sacral width at the inlet, taking 100 to represent the former.

$$\frac{\text{Sacral width at inlet} \times 100}{\text{Greatest width between iliac crests}} = \text{index,}$$

we obtain the following results:—

	Greatest Width between Iliac Crests.	Greatest Width of Sacrum at Inlet.		Index.
Males, . .	255 mm.	: 108 mm.	:: 100	: 42·3
Females, .	245 „	: 109 „	:: 100	: 44·4

Comparing with the above my own observations on the foetal pelvis, we find—

Male, . .	51·1 mm.	: 22·7 mm.	:: 100	: 44·5
Female, .	48 „	: 22·6 „	:: 100	: 47

¹ Schauta, in Müller's *Handbuch der Geburtshülfe*; Playfair, *The Science and Practice of Midwifery*; Galabin, *Manual of Midwifery*; Wood, article on Pelvis in *Todd's Cyclopædia*.

that proportions very nearly the same are observable in these specimens; and further, that the females, even in the foetal condition, possess a sacrum which bears a relatively greater proportion to the maximum pelvic width in the male, such as maintains in the adult.

Comparing now the sacral width with the transverse diameter of the inlet, supposing the latter to be 100, we find from Verneau the proportion works out as follows:—

	Max. Trans. Dia. of Inlet.	Breadth of Sacrum at Inlet.		Index.
Males, . .	130 mm.	108 mm.	:: 100 :	83
Females, .	135 „	109 „	:: 100 :	80·7

whilst the foetal pelves yield the following results:—

	Max. Trans. Dia. of Inlet.	Max. Breadth of Sacrum.		Index.
Males, . .	21·2 mm.	22·7 mm.	:: 100 :	107
Females, .	20·8 „	22·6 „	:: 100 :	108·6

From this it will be seen that the sacrum in the foetus exceeds the width of the pelvic inlet; and here it is necessary to point out that the maximum width of the sacrum in the foetus lies above the pelvic inlet,¹ whereas Verneau's figure gives a greater transverse width for the sacrum at the level of the inlet than at the base. For this reason I have taken the larger of Verneau's diameters to compare with the widest measurements in the foetus. From these facts it follows that the explanation so frequently offered of the mode of 'growth of the female pelvis,' i.e., the remarkable increase in the diameters of the sacrum, is altogether wrong, and based on a misconception of the proportions of the bones in the foetal condition. As will be shown later, the increase in the size of the diameters of the inlet of the pelvis is due in large measure to the growth and development of that part of the iliac bone which overtops and forms the upper boundary of the great sacro-sciatic notch.

¹ In this connection it is interesting to note that Sir W. Turner, in his "Challenger" Monograph, has drawn attention to the fact that "Sometimes, however, in a male pelvis the sacral breadth was more than that of the transverse diameter of the inlet. This was the case in one Australian, two Negroes, a young Andaman Islander, and one Bushman."

In regard to the length of the sacrum, and therefore also in regard to the proportion of the breadth to the length, as indicated by the sacral index, too much reliance must not be placed on the measurements of the foetal specimens. It was very difficult to measure accurately the length of the sacral segment of the vertebral column without further dissection and such destruction of ligaments as would spoil the specimens for the purpose for which they were prepared. The estimates there given of the length of the sacrum must be taken only as approximate, and the index based upon this estimate must not be accepted as absolutely accurate. Quoting again from Sir W. Turner's classic monograph, we find the following measurements and indices given:—

		Mean Length of Sacrum.	Mean Breadth at Base.	Index.
Verneau—				
Males,	. .	105 mm.	118 mm.	112·4
Females,	. .	101 „	116 „	114·8
Görtz—				
Females,	. .	...	...	118·9
Garson—				
Females,	. .	101 mm.	118·3 mm.	116·8
Carl Martin—				
?	. .	100 „	105 „	105

The measurements of my foetal specimens are as follows:—

Males,	. .	21·6 mm.	22·7 mm.	104
Females,	. .	22·7 „	22·6 „	99·7

Too much reliance must not be placed on these figures. Still they are interesting, as showing that the proportions of the breadth to the length do not differ so much from what obtains in the adult, and that the narrowness of the foetal sacrum, so often referred to in works of reference, has no existence in fact. For all practical purposes, the female sacral index, although it works out at 99·7, may be regarded as 100, under which circumstances both male and female indices fall within the *Platyhiere* group of Turner, in which the breadth of the sacrum equals or exceeds the length. It is, however, curious to note that in the male foetuses the index is higher than in the female, indicating a

proportionately greater width of sacrum in that sex, a condition the converse of what holds good in the adult.

Another comparison of some interest is to contrast the relative proportions of the length of the sacrum with the maximum pelvic height. According to Verneau's figures, the proportions in the adult are as follows, taking 100 as the pelvic height:—

	Height of Pelvis.	Length of Sacrum.			Index.
Males, . .	220 mm.	105 mm.	::	100	47·7
Females, .	197 „	101 „	::	100	51·2

My own figures for the foetal pelvis are:—

Males, . .	42 mm.	21·6 mm.	::	100	51·4
Females, .	41 „	22·7 „	::	100	55·3

In each case the length of the sacrum, as compared with the pelvic height, is proportionately longer in the female than in the male; but a comparison between the foetal and adult series will prove that during growth the relative proportions of these parts of the skeleton are little if at all disturbed. Further inquiry and special methods of measurement are, however, necessary before these observations can be accepted; none the less, the results are interesting, as they are based on measurements taken with all the accuracy possible under existing conditions.

In passing to the consideration of the cavity of the true pelvis, the reader's attention is directed to the photographs shown on Pl. XIV., and to the diagrams on p. 369. He will see at a glance that even during the foetal condition the configuration of the parts is as pronounced as what we see in the adult. Apart from the differences in the outline of the inlet, to which attention has been already directed, he will notice that in the male the walls of the true pelvis encroach much more on the cavity. This is due to their greater obliquity, as shown in fig. 1, and also to the fact that the ischial spines are more inturned, and therefore brought closer together, thus giving to the entire pelvis a funnel-shaped appearance, as contrasted with the female. These observations are supported by a reference to the measurements, wherein the average width between the ischial spines in the female foetuses is 14 mm., as compared with 12 mm. in the males. Contrasting the width between the ischial spines and the

transverse diameter of the brim, assuming the latter = 100, we get from Verneau's figures the following proportions:—

	Trans. of Brim.	Width between Ischial Spines.		Index.
Verneau—				
Males, . .	130	: 90	:: 100	: 69·2
Females, . .	135	: 108	:: 100	: 80

Comparing the foetal pelves with the above, we find the proportions as follows:—

Males, . .	21·2	: 12	:: 100	: 56·6
Females, . .	20·8	: 14	:: 100	: 67·3

The difference between the male and female proportions is in the adults (Verneau) 10·8, whilst the foetal pelves yield an almost similar figure of 10·7. The relative width between the ischial spines is, however, greater in the adult than in the foetus, and this may be explained by the fact that, unlike most of the other spinous prominences on the innominate bone, the ischial spines are not provided with secondary epiphyses,¹ so that we may assume that their growth ceases at a much earlier period, with the consequent effect of proportionably increasing the width between them in the adult.

The reaction of the slope of the pelvic walls on the outlet is also seen in the photographs and figures. For reasons already stated, I have disregarded the influence of the coccyx on the antero-posterior diameter, although in each figure it appears as it is shown in the photographs. As regards the contours of the anterior part of the pelvic outlet, the differences in form and size are well seen, and will be considered at a later stage, when the differences in the formation of the pubic arch are discussed; meanwhile, it may be pointed out that the width between the ischial tuberosities is greater in the female foetal pelvis, 20·7 mm., than in the male, 19·5 mm.

Concerning the depth of the pelvic cavity, the measurement in the male foetus, 19·8 mm., exceeds that of the females, 18·8 mm., taken from the brim near the pectineal eminence to the most depending part of the ischial tuberosity.

The proportion of the depth of the pelvic cavity in the adult

¹ I am aware that such an epiphysis has been described, but I have failed to ascertain its existence in all the specimens I have examined.

to the total height of the pelvis, taking the latter=100, as deduced from Verneau's measurements, is as follows:—

Verneau.	Total Height of Pelvis.	Depth of True Pelvis.	Index.
Males, . . .	220 mm.	107 mm. :: 100	48·6
Females, . . .	197 „	93 „ :: 100	47·2

Comparing this with my own measurements on the foetal pelvis, we find that—

Males, . . .	42 mm.	19·8 mm. :: 100	47·1
Females, . . .	41 „	18·8 „ :: 100	45·8

thus proving that there is little disturbance of these proportions during subsequent growth.

✓ A glance at the photographs and diagrams will enable the reader to realise that there is a marked difference between the angle of the pubic arch in the male and female foetuses, despite the many statements to the contrary,¹ and directly opposed to the opinion expressed by Schauta,² that the pubic arch first assumes its characteristic form in the female about the age of 12 or 13. Owing to the small size of the foetal specimens, considerable difficulty was experienced in measuring this angle. It was found that it could be much better estimated from the photographs by the use of a projector; and whilst this method may be open to criticism, it may be pointed out that the same sources of error are common to both the male and female series and further, that the results obtained had been checked by reference to the wet preparations, and found sufficiently accurate for all practical purposes. The sexual difference, however, is so marked, that it can easily be recognised without the aid of instruments when the male and female specimens are placed side by side (see Pl. XIII. and fig. 1). The average sub-pubic angle in the females is about 68°, as contrasted with 50° in the males. Verneau estimated the angle at 74° in the females and 60° in the males. Comparing these results, it will be evident that though there is an increase in the angle with the growth of the pelvis, the sexual difference is maintained throughout; for whilst the difference between the average angles of the male and female foetal pelvis amount to 18°, the difference in the adult, as shown

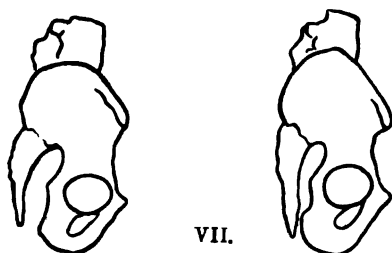
¹ Wood, *Todd's Cyclopædia*. Lusk, *Science and Art of Midwifery*. Galabin, *Manual of Midwifery*.

² Müller's *Handbuch der Geburtshilfe*.

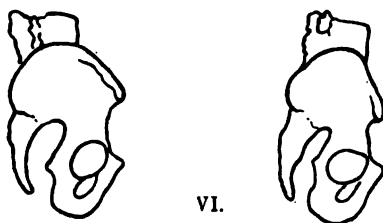
by Verneau's figures, amounts to 14° . In this connection it is interesting to note the maxima and minima in both sexes. According to Verneau, the male angle ranged from 38° to 77° , the female from 56° to 104° ; in my own specimens the extremes were 46° and 56° for the males, and 60° and 76° for the females, —the female minimum exceeding the male maximum. We must therefore regard it as established that, in degree at least, the sexual differences of the sub-pubic arch are as well marked in the foetus as in the adult.

✓ Another feature in which the adult female pelvis differs from the male is the form and size of the great sacro-sciatic notch. This in the female is usually wider and shallower than in the male. The form of the notch depends on the relation of the sacrum to the innominate bone, its shape being modified by the degree of curvature of the sacrum. ✓ The width of the notch necessarily depends on the degree of separation of the two bones which form its boundaries in front and behind, but it must be noted that this reacts on the shape of the ilium, the lower free border of which forms the summit of the notch. Here a characteristic difference is met with in the two sexes. If this part of the ilium be measured from the posterior inferior iliac spine, in correspondence with the external margin of the sacrum to the anterior margin of the great sacro-sciatic notch, the length in the females will, on an average, be found to exceed considerably the corresponding measurement in the males. The average length of this part of the ilium, which I measured in eight adult females, was 49 mm., as contrasted with 40 mm., the average which I obtained from five males. The nearest approach to this measurement which I can find in Verneau's tables is the distance between the ischial spine and the posterior inferior iliac spine: this for the males averaged 50, whilst the females yielded a mean of 51. Obviously, however, this measurement is not the same as that to which I have already drawn attention, nor is it one which appears to me at all satisfactory, as the spine is liable to much individual variation, both as regards length and direction, nor does the slight difference shown between the figures for the two sexes at all invalidate the conclusions derived from my measurements, for they are in reality different sides of a triangle, the angles of which are formed at points in correspond-

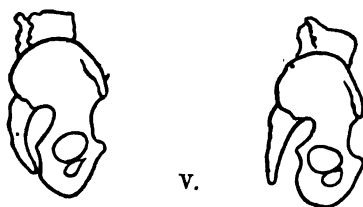
ence with the posterior inferior iliac spine, the ischial spine, and the angle formed by the anterior confluence of the anterior margin of the great sacro-sciatic notch and its upper border.



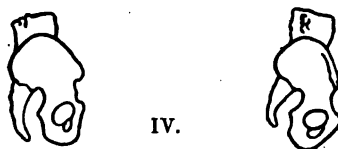
VII.



VI.



V.



IV.

Females.

Months.
FIG. 8.

Males.

The increased width of the hinder portion of the ilium is necessarily correlated with a greater breadth of the sacro-sciatic notch.

This, as Testut states, measures 72 mm. across in women as compared with 60 mm. in males, a result in harmony with the figures given above relating to the adult pelves I examined. I am aware that grave objection may be taken to any measurements of the width of the sacro-sciatic notch in foetal pelves, on the grounds that the parts are so pliable that slight compression may give rise to very considerable differences in the diameters. Further, it is necessary to remember that the measurements are so small that it is next to impossible to estimate the slight differences with accuracy. For these reasons I have not attempted to record this difference by figures, but will content myself with a reference to the photographs and diagrams carefully constructed therefrom (Pl. XV. and fig. 3). The reader will have no difficulty in recognising the fact that in the four female foetal pelves here represented the sacro-sciatic notch, and with it the hinder part of the ilium, is distinctly wider than in the male. I confess I was hardly prepared to be able to demonstrate this sexual difference in the foetus, but it seems to me to have a very far-reaching influence on the subsequent development of the pelvis. If the forms of the male and female adult innominate bone be compared, it will be seen that in the female the width of the posterior part of the ilium is greater than in the male; unfortunately, it hardly seems possible to estimate this proportional difference in the adult for comparison with the same proportions in the foetus; but the fact I wish to emphasise is, that this difference exists even during foetal life, and that during subsequent growth it is maintained, and possibly emphasised; and that it is not to be attributed to the exercise of influences such as pressure, muscular action, etc., which have been supposed in the past to act in some specially selective way in the female pelvis, whilst, for some obscure reason, the males have been exempt from the operation of these same forces.

✓ From a consideration of the facts already stated, it has, I trust, been sufficiently pointed out that in many of its forms and proportions the foetal pelvis conforms very closely to the adult. The greatest difference is met with in the innominate indices, and in the proportion of iliac width to pelvic height. The increase in the pelvic diameter, especially those of the brim, have been in the past particularly ascribed to the rapid increase

in width of the sacrum. It was assumed—without, so far as I know, any fact to support it—that the sacrum was relatively narrower in the foetal pelvis. Not only is this not the case, but I trust I have been able to show that its width is proportionately greater to the rest of the pelvis than in the adult, (see p. 371). Such being the case, the explanation that the increase in the transverse diameter is due to its great proportional increase in width necessarily falls to the ground. It is in the posterior part of the ilium that growth most rapidly occurs, thus leading to greater proportional increase in the antero-posterior diameters of the pelvis, as well as augmenting its transverse width; but the fact that this difference in the form of the ilium is already clearly displayed in the foetus proves that during growth the relative proportions of the sexes are maintained throughout. Hubert and Valerius,¹ in discussing the growth of the pelvis, describe the transverse diameter of the pelvic canal as increasing by the horizontal evolution of the sacrum and *the hind parts of the ilia*, the antero-posterior by those of the iliac bones alone.

So far, I have confined myself to the description of those features of the foetal pelvis which are characteristic of sex. I have not discussed the changes which take place in the position of the sacrum, the development of the sacral promontory, and the obliquity of the pelvis. These lie outside the scope of the present inquiry, and doubtless are largely dependent on mechanical cause associated with the assumption of the erect position. But what I do desire to insist upon is, that these influences operate alike in the two sexes, and are in no way responsible for the remarkable differences met with in male and female adult forms, these being due to an inherent difference in the forms of the bones and cartilages.

Another feature of possible importance is suggested by a consideration of the photographs in Plate XV. As will be seen, the pelvis have been placed for comparison in a position in which the anterior superior iliac spines and the symphysis pubis occupy the same vertical plane. Now, a comparison of the two series reveals the fact that in the females the lumbar part of the columna appears to curve upwards and backwards, whilst in the males it is more inclined forwards. This circumstance, which

¹ *Memoires de l'Academie Royale de Médecine de Belgique*, tome iv.

can hardly be considered accidental, appears to suggest that the mode of articulation of the ilium with the sacrum differs in the two sexes, a fact no doubt correlated with the difference in the form and size of the hinder portion of the ilium already alluded to, and would appear to indicate that even in foetal life there was a characteristic difference in the obliquity of the pelvis of the two sexes such as maintains in the adult. It would be unwise, however, to draw any conclusions from so small a number of specimens, though my examination of other foetal pelves appears to confirm this view.

✓To sum up, it appears from a consideration of the foregoing facts that during foetal life the essentially sexual characters are as well defined as they are in adult forms, and that any differences that occur during growth between the adult and foetal forms, due it may be to the influence of pressure or muscular traction, affect both sexes alike, and that such influences are in no way accountable, as has been maintained, for the characteristic features of the pelves of the female as contrasted with the male.✓

Note.—Since the foregoing was written, I have had an opportunity of consulting Fehling's paper, but I have considered it advisable, under the circumstances, not to alter my communication, but to present it in its present form, as evidence confirmatory in the main of Fehling's views.

PHOTOGRAPHS OF A SERIES OF SECTIONS OF AN
EARLY HUMAN EMBRYO. By B. H. BUXTON.
(PLATES XVI.-XXVII.)

Estimated age, 25 days.

Ovum—Size of pigeon's egg, covered with shaggy villi.

Embryo—Length, 5 mm. Thickness, 2 mm.

Taken fresh from uterus after hysterectomy, and kept for a year in 2 per cent. formalin before hardening.

Hardened in absolute alcohol, imbedded in celloidin, and cut in 112 serial sections, each 20 micro-millimetres thick. Stained with hæmatoxylin and eosin.

Photographs.

25 diameters, Spencer, 2 in. No ocular.

100 diameters, Spencer, $\frac{1}{2}$ in. Zeiss projection ocular.

180 diameters, Spencer, $\frac{1}{4}$ in. „

500 diameters, Leitz, $\frac{1}{12}$ oil. „ immersion.

The embryo is lying on its right side, and the sections are cut sagittally from left to right.

The first six plates are in regular order from left to right, and the numbers are those of the sections.

SPECIAL POINTS.

Allantois.—The cavity of the stalk can be traced a short distance from the cloaca. It then appears to close up. The cavity of the yolk stalk is open, and continuous with that of the intestine.

Alimentary Canal.—The pituitary involution forms an unbranched tubule, extending upwards between the fore and hind brain from the roof of the mouth.

The hyomandibular and three branchial pouches can be clearly traced. A septum, containing no mesoblast, separates them from the corresponding grooves. From the œsophagus, the laryngeal

chamber branches off, and the trachea divides into two primary bronchi, but there are no secondary branches.

The stomach shows as an elongated dilatation.

The pancreas and bile-duct are present in early stages.

The liver is already of considerable size, and richly supplied with blood.

The vitelline loop extends outside the embryo, its cavity being continuous with that of the yolk stalk.

Beyond the vitelline loop the intestine dilates slightly, and then contracts again to form the rectum, which opens into the cloaca.

Beyond the cloaca is the narrow post-anal gut, which shows, however, a marked dilatation at its caudal extremity.

Circulatory.—Heart: Single auricle and ventricle, from which latter arises the truncus arteriosus. Arches I. and II. are obliterated, but III., IV., and V. can be traced on either side to the anterior dorsal aortæ, which join about opposite the lungs to form the single dorsal aorta, which, after giving off the vitelline artery, divides into the allantoic arteries a little anterior to the cloaca. The remnant of the dorsal aorta continues as the caudal aorta.

The blood is returned by the allantoic and vitelline veins, which unite, partly breaking up in the liver to form the portal system, and partly running directly into the sinus venosus by means of the ductus venosus.

The cardinal veins, running dorsally to the Wolffian bodies, return the blood from the embryo, the anterior and posterior on either side combining to form the Cuvierian veins, which empty into the sinus venosus.

Nervous System.

Cranial flexure is marked. Of the cranial nerves,—

- V. Supplies the mandibular arch.
- VII. „ the hyoid arch.
- VIII. „ the ear.
- IX. „ the first branchial arch.
- X. „ the 2nd and 3rd branchial arches.

The cervical nerves V.-VIII. and 1st dorsal join to form the brachial plexus.

There is no trace of the sacral plexus.

Skeletal.—The notochord cannot be traced further forward than a point opposite the hyoid arch, but from that place to the extreme end of the tail is well marked. It exhibits several dilatations, one of which is shown on Plate XXVII., *d*.

No head cavities or muscle plates anterior to those of the hypoglossal region can be found.

Muscle plates of hypoglossal region: Three distinct plates can be seen on either side; the anterior plate appears to split up, and may perhaps be considered to represent two plates, which would make up the usual number of four.

The dorsal muscle plates are differentiated into muscular and dermal layers, except in their more ventral portions.

The fore and hind limbs appear as buds, composed of undifferentiated cells.

Genito-Urinary.—The Wolffian ducts commence just behind the lung, and run posteriorly outside the Wolffian bodies to the cloaca. Just before the ducts reach the cloaca the ureters appear as evaginations from them.

Special Sense Organs.

Eye.—The optic vesicle buds off from the fore-brain, the lumen being still wide open. It rises up to form the optic cup, of which the retinal is already somewhat thicker than the pigmentary layer. The choroidal fissure is well marked, and the vesicle of the lens is still open to the exterior.

The Ear forms an elongated, roughly quadrangular sac, closed off from the exterior. Closely connected with its vestibular portion is the ganglion of the eighth nerve.

The Nose.—Olfactory plates are present as thickened ridges of the epiblast, but there are as yet no involutions to form the olfactory pits.

DESCRIPTION OF PLATES XVI.-XXVII.

Pl. XVI. (25 diameters).—1, chorion ; 2, yolk sac and stalk ; 3, 4, (23), ear and branchial arches.

Pl. XVII. (25 diameters).—5, 6, (26), optic cup, branchial arches, heart ; 7, 8, (34), truncus arteriosus, post-anal gut.

Pl. XVIII. (25 diameters).—9, 10, (40), larynx—œsophagus ; 11, 12, (43), ureters and allantois.

Pl. XIX. (25 diameters).—13, 14, (60), sinus venosus, gall-bladder, pituitary involution ; 15, 16, (70), brain.

Pl. XX. (25 diameters).—17, 18, (78), sixth cervical nerve, optic vesicle ; 19, 20, (78), Wolffian bodies, transverse section.

Pl. XXI. (25 diameters).—21, 22, (83), Wolffian bodies ; 23, (92), Wolffian bodies on right and muscle plates on left of dorsal aorta. To extreme right is the optic vesicle and vesicle of lens ; 24, (101), spinal cord—longitudinal section. The muscle plates on either side. On left—central transverse section. On right—ventral transverse section.

Pl. XXII. (100 diameters).—25, sinus venosus. The ductus venosus runs into it on the left, and the Cuvierian vein on the right. Above is the auricle, and below the lung—(see Pl. XIX., 14) ; 26, allantoic arteries branching off on either side from the posterior end of the dorsal aorta, and enclosing the Wolffian ducts and rectum ; 27, spinal cord. On either side the ganglia, and further out the muscle plates. Below is the notochord, and below this the dorsal aorta—(see Pl. XX., 19) ; 28, ear and ganglion of eighth nerve—(see Pl. XVI., 3).

Pl. XXIII. (Eye series).—29, 30, 31, 100 diameters—32, 180 diameters.—29, optic vesicle budding off from fore-brain—(see Pl. XX., 19) ; 30, optic vesicle rising up to form optic cup ; 31, optic cup and choroidal fissure—(see Pl. XVII., 5) ; 32, vesicle of lens—(see Pl. XVI., 3).

Pl. XXIV. (Ureter series)—100 diameters.—Ureters and cloaca. Serial sections.—On the left in 33 is the dilated posterior extremity of the Wolffian duct, and the following photographs show that the ureter is formed by evagination from this.

Pl. XXV. (180 diameters).—37, chorionic villus—(see Pl. XVI., 1) ; 38, sixth cervical nerve—(see Pl. XX., 19) ; 39, caudal dilatation of post-anal gut—(see Pl. XVII., 7) ; 40, pituitary involution—(see Pl. XIX., 13).

Pl. XXVI. (41, 100 diameters ; 42, 43, 44, 180 diameters).—41, larynx and œsophagus—(see Pl. XVIII., 9) ; 42, muscle plates of hypoglossal region ; 43, muscle plates, central transverse section—(see Pl. XXI., 24) ; 44, muscle plates, ventral transverse section—(see Pl. XXI., 24).

Pl. XXVII. (45, 46, 47, 180 diameters ; 48, 500 diameters).—a, septum dividing first branchial pouch from first branchial groove ; b, Wolffian duct and tubules ; c, Wolffian body, showing glomeruli ; d, notochord.

[The number in brackets is that of the section, the current numbers are those of the figures in the several plates.]

INDEX.

- | | |
|--|---|
| <p> A A, allantoic artery.
 A C, carotid artery.
 A CA, caudal aorta.
 A D, dorsal aorta.
 ALL, allantois.
 AMN, amnion.
 A R—III, IV., V., arterial arches.
 AU, auricle.
 A V, vitelline artery.
 B D, gall-bladder.
 B F, fore-brain.
 B H, hind-brain.
 B M, mid-brain.
 B R—I, II, III., branchial arches.
 CAP, capsule of kidney.
 CB, cerebellum.
 C F, choroidal fissure.
 CH, notochord.
 CL, cloaca.
 C N VI., sixth cervical nerve.
 C O E, body cavity.
 C V, chorionic villi.
 D V, ductus venosus.
 G B—I, II, III., branchial grooves.
 G G, ganglion.
 G H M, hyomandibular groove.
 H Y, hyoid arch.
 I N F, infundibulum.
 I N T, intestine.
 L F, fore-limb.
 L G, lung.
 L H, left horn of sinus venosus and hind limb.
 L I, liver. </p> | <p> L V, vesicle of lens.
 L X, larynx.
 M E S, mesentery.
 M N, mandibular arch.
 M P, muscle plate.
 M Y, spinal cord.
 A, œsophagus.
 O L, olfactory plate.
 O V, optic vesicle.
 P A, body wall.
 P B—I, II, III., branchial pouches.
 P G, post-anal gut.
 P H, pharynx.
 P H M, hyomandibular pouch.
 P T, pituitary involution.
 R H, right horn of SV.
 R V, recessus vestibuli.
 S T, stomach.
 S V, sinus venosus.
 T H, thyroid.
 T I, tuberculum impar.
 T R, truncus arteriosus.
 U R, ureter.
 V, vein.
 V A, vein allantoic.
 V C A, „ cardinal.
 V C U, „ Cuvierian.
 V V, „ vitelline.
 V E N, ventricle.
 W B, Wolffian body.
 W D, Wolffian duct.
 Y C, cavity of yolk stalk.
 Y S, yolk stalk. </p> |
|--|---|

**THE PELVIC SPLANCHNIC NERVES: AN EXAMINATION
INTO THEIR RANGE AND CHARACTER. By N. BISHOP
HARMAN, B.A., M.B. (Cantab), F.R.C.S. (Eng.), *Hutchinson
Student, St John's College; Demonstrator of Anatomy, Cam-
bridge University.* (PLATES XXVIII.-XL.)**

THE name 'pelvic splanchnic nerve' has here been applied to those parts of the sacral plexus distributed to the pelvic viscera, as suggested by Gaskell, for it appears to supply an appellation more convenient than the more commonly used 'nervus erigens,' in that it indicates a nerve located in a certain position, and having a certain general distribution, without committing one to any definition as to the functions of the nerve. Such a definitive, yet non-committing, name would seem to well fit it with an ideal nomenclature such as Huxley craved.¹

The Nerve in Man.

The early descriptions of the nerve are mostly found in connection with work on the uterine nerves, in dissections of adult and foetal subjects, but the references to the particular origin of the pelvic splanchnics are not very full. Willis, Eustachius, and Haller were among the early workers on these parts. The work of Jo. Gottl. Walter (1) is of a specially noteworthy character. The illustrated descriptions by Tiedemann (2) of the uterine and sacral nerves are well known, and his figures appear to have formed the basis of many text-book diagrams.

Two English workers follow—Robert Lee (3) and Thomas Snow Beck (4)—both of whom refer to the connection of the sacral nerves with the pelvic viscera. The latter is very explicit in his description, and draws an analogy between the arrangements of the abdominal splanchnics and these visceral sacral branches.

The work of Hirschfeld and Leveillé (5) is well known, their figures appearing in the text-books of to-day. In the mono-

¹ On the crayfish.

graph of Frankenhaeuser (6) on the uterine nerves, their sacral connections are carefully noted and shown in the admirable illustrations.

The results of the more recent of these dissections give the origin of the pelvic splanchnics as being mainly from the third sacral nerve, whilst smaller portions arise from the second or fourth nerves, rarely from both.

The Nerve in Lower Animals.

With the growth of experimental examination of nerves, subsequent to the work of Bell, we find numerous investigations into these nerves. Of these, the following may be mentioned here:—

Budge (7) may be credited with the earliest efforts. He showed from experiments on dogs that the bladder was innervated by two sets of nerves,—one from the hypogastric plexus, the other from the anterior roots of spinal nerves, including the first, second, and third sacral.

Gaskell (8) also showed on the dog “an outflow of nerve fibres of the smallest calibre from the second and third sacral nerves (30th and 31st spinal); these constitute the main portion of the nervi erigentes . . . they send branches in two directions, upwards to the inferior mesenteric ganglion, and downwards to the bladder, rectum, and generative organs.”

Langley (9) found in the rabbit that a set of motor fibres reached the pelvic viscera from the second, third, and fourth sacral nerves, perhaps also from the first. The majority issued from the third and fourth.

Sherrington (10) gives the results of his experiments and dissections on two animals, the cat and a monkey (*Macacus rhesus*).

Cat.—In post-fixed plexus, origin from sub-thoracic nerves VIII, IX, and X. In pre-fixed plexus, arising from sub-thoracic nerves VII, VIII, IX, and X. Here the VIII sub-thoracic equals the I sacral.

Monkey.—Post-fixed—sub-thoracic nerves VIII, IX, and X. Pre-fixed—sub-thoracic nerves VII, VIII, IX, and X. Here the VII sub-thoracic equals the I sacral.

Langley (11) gives their origin in the cat from the II sacral in the main, with a variable number of fibres from the I and III sacral. These nerves he believes to be comparable to the II, III, and IV sacral in man.

Griffiths (12) describes the nerves in the dog as arising usually by two roots, one large and one small, the larger arising from the II sacral, the smaller usually from the first, but sometimes from the third, or there may be two small roots from both first and third. These nerves he describes as being almost entirely composed of small medullated fibres, measuring from 2 to 3 μ in diameter.

Langley and Anderson (13), in a detailed examination into the constitution of the nerves in the cat, find that a complete nerve contains normally about 3500 medullated fibres; of these, one to two dozen are from 7 to 12 μ in diameter, several hundreds are 4 to 5 μ , and nearly all the rest are quite small.

Present Examination—Methods and Scope.

In this examination into the nerve in the human subject, I have endeavoured to obtain results similar to those obtained in my earlier examination of the lumbar rami (14), and to those obtained by Langley and Anderson for the cat.

The complex arrangements of the pelvic nerves have necessitated more elaborate methods than those adopted for the lumbar nerves. Fetuses ranging from the seventh month (39 cm.) to full time (55 cm.) were used. The subjects were dissected immediately on receipt in the fresh state; the sacral nerves having been severed high up in the spinal canal, the whole plexus and its connections were removed and placed in osmic acid (1 per cent. solution) for twenty-four hours, then in weak alcohol for a short time.

The plexus was now arranged in a dissecting-trough according to the beads affixed to the various nerves, and the sketch previously made for recognition purposes. Lengths of the II, III, and IV sacral nerves were then removed for embedding.

The grosser connective tissue being removed, the nerves were exposed to the action of a 10 per cent. solution of nitric acid for the purpose of softening the remaining connective tissue.

This softening is, in most cases, necessary, for otherwise it is rarely possible to retain the plexus in anything approaching the natural position during dissection. It has, however, the disadvantages of removing some of the osmic stain, and of softening the nerves. To avoid damage to the nerves, it seems better to examine their condition whilst exposed to the acid, rather than to work by a time limit. (See Note, p. 393.)

The nerve strands forming the pelvic splanchnics were then cleaned, their proximal ends freed from neighbouring strands, and their ultimate source noted. Parts of these strands were excised, teased out, and the characters and number of the nerve fibres therein ascertained. It was found to be impracticable to make anything like a reasonably accurate individual count of such a mass of small fibres, I therefore estimated their numbers with the aid of a micro-millimetre eyepiece; the number of fibres in one bundle of a preparation having been counted individually, the contents of the remaining bundles were estimated by comparison of size to the counted bundle.

These methods of investigation were employed in six cases in all, which, from the use of both sides, give twelve plexuses. The greater number of these are of the male sex, the difficulty in obtaining fresh material prevented a more equal selection of subjects.

Appended are the drawings of the various plexuses. Each of these is the result of the superposition of two drawings,—one that of the plexus exposed by simple dissection, the other the result of the minute dissection of the pelvic splanchnics with the aid of the simple microscope. To each of these corresponds an analytical table giving the results of the examination of the plexus and of each nerve strand, and from these analyses a general table has been prepared which states the form of plexus found, the number of fibres in connection with each spinal nerve, and the average number for each, from nerves 27 to 29 inclusive.

Results.

From the table it will be seen that the main outflow of the pelvic splanchnic nerve is from the 28th spinal, or III sacral nerve; the outflow by the 27th and 29th nerves is seen to vary

ANALYSIS OF SPLANCHNIC NERVES.

Mark of Subject.	Sex.	Length or Age.	Side of Body.	Form of Plexus.	Nerve 27 = II. Sac.		Nerve 28 = III. Sac.		Nerve 29 = IV. Sac.	
					No. of Strands.	No. of Fibres.	Strands.	Fibres.	Strands.	Fibres.
M	♀	54 cm.	Right.	Nv. furcal. = $\frac{1}{2}$ IV. Lmb. Sup. Glut. = 5,1,4.	0	...	2	535	6	2405
			Left.	Nv. furcal. = $\frac{1}{2}$ IV. Lmb. Sup. Glut. = 5,1,4,2.	0	...	3	1165	6	2020
G	♂	50 cm.	Right.	<i>XII Rib absent.</i> Nv. furcal. = $\frac{3}{4}$ 24th Spinal. Sup. Glut. = 4,5,1.	2	280	6	1710	2	50
			Left.	Do.	3	340	6	1990	0	...
H	♂	46 cm.	Right.	Nv. furcal. = $\frac{1}{2}$ IV. Lmb. Sup. Glut. = 5,1,2,4.	1	20	4	1400	2	170
			Left.	Nv. furcal. = < IV. Lmb. Sup. Glut. = 5,1,4 (2 f)	0	...	5	Staining defective.	3	Staining defective.
N	♂	53 cm.	Right.	Nv. furcal. = All IV. Lmb. ex. abt. one-tenth part to Obturator av. sup. Glut. = 4,5,1. Lcv. Ant. = 2,3,4.	2	550	6	2600	1	320
			Left.	Nv. furcal. = $\frac{1}{2}$ IV. Lmb. Sup. Glut. = 4,5,1. Lcv. Ant. = 2,3,4.	3	890	5	2300	1	500
K	♀	39 cm.	Right.	<i>XII Rib absent.</i> Nv. furcal. = $\frac{3}{4}$ 24th Spinal. Sup. Glut. = 4,5,1.	1	150	4	510	1	50
			Left.	Do.	3	300	4	700	0	...
L	♂	55 cm.	Right.	Nv. furcal. = $\frac{3}{4}$ IV. Lmb. Sup. Glut. = 5,4,1.	0	...	7	2425	2	570
			Left.	Do.	2	300	8	2700	1	420
Averages :—					1.5	200	5	1620	2	590

considerably; that in connection with the 29th nerve contains most commonly a greater number of fibres than that arising from the 27th nerve. In no case could I trace any connection with the 26th spinal nerve.

The sizes of the nerve fibres are similar to those given for other animals, being in the main of the small medullated class, and measuring from one to three micro-millimetres in diameter. There is also a small and variable number of larger fibres.

In two instances (K left and L left) serial sections were taken of the splanchnic nerve and its sacral connections, from the sacral roots to the appearance of ganglia within the pelvic plexus upon the bladder-walls. The details of these two plexuses, as given in figs. 10 and 12, were added to the drawings of the simple dissections from these serial sections.

The relation of the age of the foetus, as indicated by its length, to the number of medullated fibres in the pelvic splanchnic, is noteworthy.

The general average works out at	2400
The average for subjects of above 50 cm. length	3240
The average for subjects 50 cm. length and below	1540

The variation is doubtless due to the degree of development of the medullated sheath.

Sacral Branch to the Hypogastric Plexus.

In the reference given above to Gaskell's paper (8), there will be noticed the statement that, in the dog, branches of the pelvic splanchnic pass upwards to the inferior mesenteric ganglion. Langley and Anderson (15), working by degeneration methods on the cat, find that in that animal:—(a) the sacral nerves may send to the hypogastric nerve of the same side two or three fibres which rise in the nerve for at least two-thirds of its course; (b) besides these, several fibres pass from the sacral nerves to the hypogastric nerve, and thence curl backwards and run to the bladder, etc.

Quain (16), referring to this point, says, "a few of the pelvic splanchnic fibres may turn upwards to the inferior mesenteric ganglion"; but it is not quite clear whether the reference is to a dissection in the human body, or the suggestion of a possible

likeness to that found in the dog by Gaskell. In my dissections of the human subject no such upward branches could be found. The splanchnics mingled with the hypogastrics in the pelvic plexus, and those fibres which were found to be in loose connection with the hypogastrics before the meeting in the plexus, could be traced thence into the plexus and to the bladder. No direct passage of fibres from one to the other of the supplying nerves could be found. As to the presence of fibres similar to the few ascending fibres in the cat, these were found by degeneration methods; simple dissection cannot decide their presence or absence.

Relative Proportion of Hypogastrics and Pelvic Splanchnics.

In comparing the plexuses of two subjects in which minute dissection had not been begun, the sizes of the pelvic splanchnics and of the hypogastrics seemed to suggest the possibility of some proportion between them, in the direction of an inverse ratio, for the hypogastrics of the one body appeared small in comparison with the splanchnics, whilst in the other body there was a reverse appearance. Subsequent dissection did not bear out this apparent proportion.

Forms of Plexuses.

I have used as guides for the classification of the plexuses the size of the contribution of the 24th spinal nerve to the lumbosacral cord and the ultimate origin of the superior gluteal nerve. These form a reliable and at the same time readily ascertainable indicator.

Examination of the table of results given here, and of the paper on the lumbar rami (14), will show that the forms were most commonly those of the medium and rather anterior varieties, and that when a marked diversion from the average has been found, it has been in favour of the anterior forms, as witness the three cases in which only eleven ribs were present. These cases therefore support Rosenberg's theory of the phylogenetic shortening of the vertebral column, and are against Paterson's contention on this point (17).

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n.f., nervus furcalis. *q.f.*, nerve to quadratus femoris. *o.i.*, nerve to obturator internus. *g.s.*, great sciatic nerve. *g.s.per.*, do., peroneal division. *g.s.pop.*, do., int. popliteal division. *sp.gl.*, superior gluteal nerve. *p.y.*, nerve to pyriformis. *s.s.*, small sciatic nerve. *i.gl.*, inferior gluteal nerve. *pd.*, pudic nerve. *p.spl.*, pelvic splanchnic nerve. *hyp.*, hypogastric nerve. *p.pl.*, pelvic plexus on bladder. *l.a.*, levator ani nerve.

Note.—I have since obtained better results in loosening the connective tissue by prolonged soaking in water 98, glycerine 1, nitric acid 1; thus were treated 'M' and 'N,' which replace earlier dissections. 'L' was not treated with acid, it being a remarkably open plexus.

'M.' right. ♀. 54 cm. *Analysis* :—

Nerve.	Ramus.	Fibres.	Total.
II. s.	0	...	...
III. s.	1	35	
"	2	500	535
IV. s.	3	450	
"	4	500	
"	5	675	
"	6	320	
"	7	160	
"	8	300	2405

'M.' left. ♀. 54 cm. *Analysis* :—

Nerve.	Ramus.	Fibres.	Total.
II. s.	0	...	...
III. s.	1	255	
"	2 ⁽³⁾	780	
"	3	180	1165
IV. s.	4	170	
"	5 ⁽³⁾	370	
"	6 ⁽⁴⁾	490	
"	7 ⁽²⁾	320	
"	8 ⁽²⁾	190	
"	9	480	2020

[The small figure bracketed after the index number of the ramus indicates the number of distinct bundles within the ramus.]

'G.' right. ♂. 50 cm. XIIth Rib absent. *Analysis* :—

Nerve.	Ramus.	Fibres.	Total.
II. s.	1	120	280
"	2	160	
III. s.	3	70	1710
"	4	350	
"	5 ⁽²⁾	{ 240 450 }	
"	6	400	
"	7	200	
IV. s.	8	20	50
"	9	30	

'G.' left. ♂. 50 cm. XIIth Rib absent. *Analysis* :—

Nerve.	Ramus.	Fibres.	Total.
II. s.	1	160	340
"	2	280	
III. s.	3 ⁽²⁾	{ 200 300 }	1990
"	4	240	
"	5	300	
"	6	450	
"	7	350	
"	8	150	
IV. s.	Nil.	Nil.	Nil.

'H.' right. ♂. 46 cm. *Analysis:—*

Nerve.	Ramus.	Fibres.	Total.
II. s.	1	20	20
III. s.	2 ⁽²⁾	350	1400
"	3 ⁽²⁾	450	
"	4	200	
"	5	400	
IV. s.	6	70	170
"	7	100	

'H.' left. ♂. 46 cm. *Analysis:—*

Nerve.	Ramus.	Fibres.	Total.
II. s.	Nil.	Nil.	Nil.
III. s.	1-5	Staining defective.	
IV. s.	6-7	"	

'N.' right. ♂. 53 cm. *Analysis* :—

Nerve.	Ramus.	Fibres.	Total.
II. s.	1 ⁽²⁾	300	550
"	2 ⁽²⁾	250	
III. s.	3	220	2600
"	4	500	
"	5 ⁽²⁾	480	
"	6	600	
"	7	300	
"	8	400	
IV. s.	9	320	320

'N.' left. ♂. 53 cm. *Analysis* :—

Nerve.	Ramus.	Fibres.	Total.
II. s.	1 ⁽³⁾	300	890
"	2	210	
"	3	380	
III. s.	4	110	2030
"	5 ⁽²⁾	700	
"	6	350	
"	7	400	
"	8 ⁽⁴⁾	470	
IV. s.	9	500	500

'K.' right ♀ 39 cm. XIIth Rib absent. *Analysis* :—

Medullation incomplete.

Nerve.	Ramus.	Fibres.	Total.
II. s.	1	150	150
III. s.	2	70	510
"	3	90	
"	4	150	
"	5	200	
IV. s.	6	50	50

'K.' left ♀ 39 cm. *Analysis* :—

Details of this Plexus from serial sections.

Nerve.	Ramus.	Fibres.	Total.
II. s.	1 ⁽³⁾	300	300
III. s.	2	100	700
"	3	250	
"	4	150	
"	5	200	
IV. s.	...	Nil.	Nil.

'L.' right. ♂. 55 cm. *Analysis* :—

Nerve.	Ramus.	Fibres.	Total.
II. s.	Nil.	Nil.	Nil.
III.	1	470	
"	2	220	
"	3	520	
"	4 ⁽²⁾	575	
"	5 ⁽²⁾	210	
"	6	150	
"	7	280	2425
IV. s.	8	320	
"	9 ⁽²⁾	250	

'L.' left. ♂. 55 cm. *Analysis* :—

Details of this Plexus from serial sections.

Nerve.	Ramus.	Fibres.	Total.
II. s.	1	130	300
"	2	270	
III. s.	3 ⁽⁸⁾	700	2700
"	4	450	
"	5	160	
"	6 ⁽²⁾	820	
"	7	570	
IV. s.	8	120	420
"	9	300	

UNILATERAL RENAL APLASIA; "UNSYMMETRICAL KIDNEY." By FREDERICK CRAVEN MOORE, M.D., M.Sc. (Vict.), *Demonstrator and Assistant Lecturer on Pathology, Owens College; Assistant Pathologist to the Cancer Pavilion, Manchester.*

(From the Pathological Laboratory, Owens College.)

CONGENITAL absence of one kidney seems to be such an uncommon condition, and one of such importance to the surgeon and interest to the anatomist, that I venture to place on record a typical example which recently came under my observation.

The patient in whom this condition was discovered was a man aged 55 years; he was admitted to the cancer pavilion with symptoms of rectal cancer, and eventually died from exhaustion. At the *autopsy*, thirty hours after death, the body was found to be fairly nourished, and weighed 118 lbs. Beyond the primary cancerous lesion in the upper part of the rectum and numerous metastatic deposits in the liver, no other abnormal features were met with until the genito-urinary system was examined, when it was noted that no kidney was present in the right loin. After removing the intestines, the retro-peritoneal tissue was carefully examined, but no trace of kidney, ureter, or renal vessels could be found. The right suprarenal capsule was present in its normal situation, and appeared somewhat flattened out.

The left kidney was present in the usual situation, and was obviously much larger than normal, its lower end reaching to within half an inch of the iliac crest, whilst its upper end remained in contact with the spleen. The structures entering the hilum preserved their normal relations; the renal vein appeared to be larger than usual, as also did the renal artery, which was single; the ureter also appeared to be slightly increased in diameter.

The left suprarenal capsule presented nothing abnormal. The kidney, although considerably increased in size, was quite

normal as regards shape; it weighed 256 grammes (weight of two normal kidneys in the male at 25 years = 277 grammes, Vierordt (31); between 50 and 60 years = 258 grammes, Thoma (30)); that is, a percentage weight of 0·47 as compared with the body-weight (normal percentage weight of both kidneys = 0·46, Vierordt), and its dimensions were as follows:—

Length, . . .	14·75 cm.	[normal, 10 cm. Vierordt].
Greatest breadth, 7·5	„	[normal, 6 „ „].
Breadth at hilum, 5·6	„	
Thickness, . . .	4·5 „	[normal, 3·5 „ „].

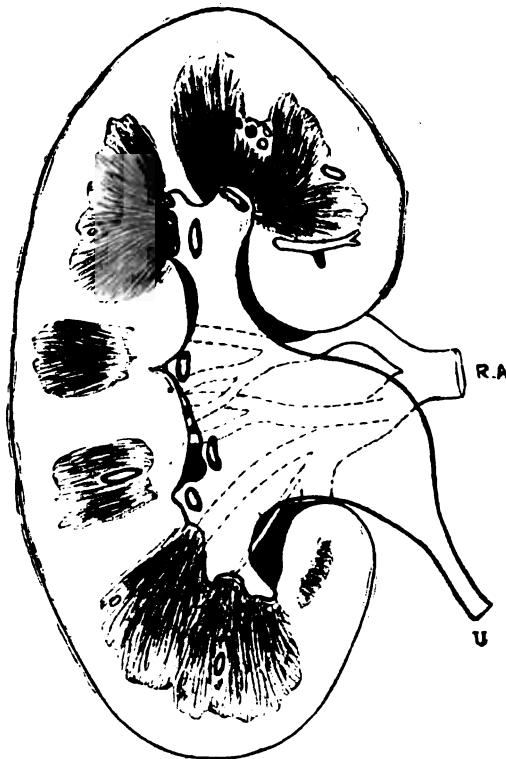


FIG. 1.—Vertical median section of the left kidney, seen from behind. (3.)

In weight, relative and absolute, the organ was equal to two normal kidneys, and in size it exceeded the normal in every dimension, and especially in length; still, neither the kidney nor

the pelvis, which was of proportionate size, showed any indication of duplication.

A vertical median section of the organ (fig. 1) showed the pyramids to be proportionately enlarged, but apparently not increased in number; the papillæ were furnished with eight calices.

To the unaided eye, the renal parenchyma appeared quite

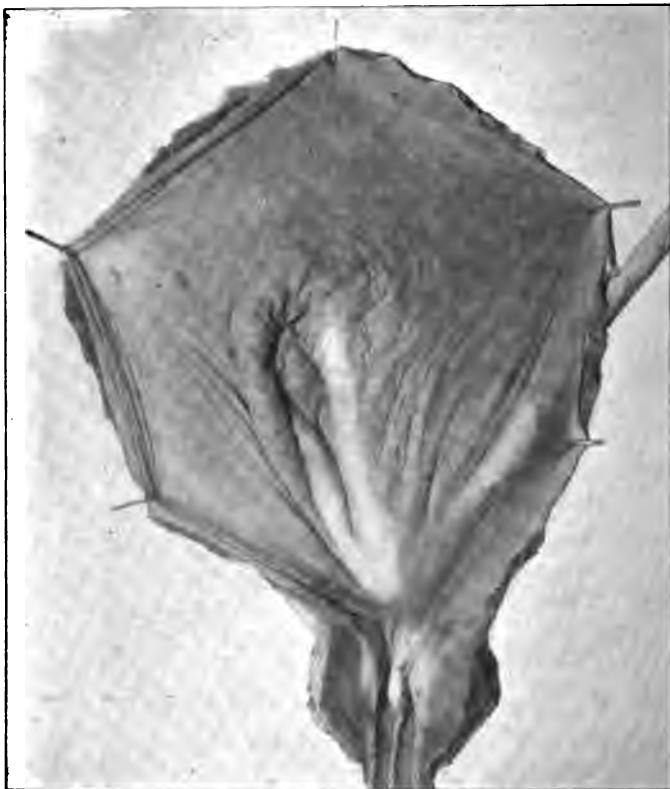


FIG. 2.—Interior of bladder and prostatic urethra. (*From a photograph.*)

healthy. On tracing the ureter downwards it was found to enter the bladder on the left side in the usual situation; the inner aspect of that viscus showed a corresponding orifice, and a well defined plica ureterica running from it to the urethral

orifice; on the opposite side there was no indication of either ureteral orifice or plica (fig. 2).

Associated with this congenital defect of the urinary system, a similar unilateral aplasia of the sexual organs existed, the testis, vas deferens, vesicula seminalis, and ejaculatory duct of the right side being completely absent, whilst the corresponding structures on the opposite side appeared larger than normal.

The prostate also presented a corresponding asymmetry, owing to the left lateral lobe being larger than the right.

On opening up the prostatic urethra, a well defined ejaculatory orifice was seen to the left of the prostatic utricle, but no corresponding orifice on the opposite side. The prostatic utricle itself was small, not exceeding $\frac{1}{8}$ inch in length, and having an orifice considerably smaller than that of the ejaculatory duct.

Microscopic examination of the Kidney.—

Almost immediately after the organ had been removed from the body it was placed in 'formol' (4 p.c.), and subsequently thin median slices were hardened in alcohol. Wedge-shaped pieces of these, each including the whole vertical median section of a pyramid, were imbedded in celloidin, cut, stained, and mounted in Canada balsam. The kidney presented no morbid changes beyond a slight granularity and vacuolation of some of the cells of the convoluted tubules, a condition not uncommonly met with in cancer cases. In several such sections measurements of the diameters of the convoluted tubules and glomeruli were made, with the following results:—

Average diameter of 100 convoluted tubules = .065 mm.

Average diameter of 100 glomeruli . . . = .21 „

Compared with the measurements given by Vierordt for the normal kidney, viz., .05 mm. and .20 mm. respectively, these appear abnormally great; more especially does this appear so when the area of the transverse section of the tubule or glomerulus is considered.

To obviate as far as possible the influence of the method of preparation of the tissues for examination, an influence which is undoubtedly a great source of fallacy in any such measurements, a kidney, apparently quite healthy, also from a cancer

case, was treated in precisely the same way, and similar measurements made, with the result that the average diameter of 100 convoluted tubules was found to be .064 mm., and that of 100 glomeruli .21 mm. The striking difference between the first series of dimensions and those given by Vierordt thus appears to be due to the peculiar effect of formol in swelling the tissues, rather than to any absolute increase in size over and above the normal.

As regards the number of glomeruli, they appeared neither more nor less numerous in the cortex of the large kidney than in one of normal size, enumerations of equal areas in each giving practically identical results.

It would thus appear that this 'unsymmetrical kidney' depended for its large size, not upon any increase in size (*hypertrophy*) of its elements, but rather upon an increase in their number (*hyperplasia*); that it was, as regards weight, volume, and minute structure, a double kidney.

Although a considerable number of examples of 'unsymmetrical kidney' have been placed on record, still the condition is of sufficient infrequency to merit the appellation 'rare.' Thus 3 cases only were found by Morris (15) among the records of 11,978 autopsies which had been performed at four London hospitals during periods of ten years. Other observers, with one exception, give a somewhat greater frequency: thus Sangalli (25) found 3 cases in 5348 autopsies; Menzies (13), 2 cases in 1790 autopsies; Rootes (23), 1 case in 600 autopsies; Petersen (20), 1 case in 1500 autopsies; while Weir (32) gives the frequency as 1 in 5000 bodies.

Averaging these statistics, one may say that the 'expectation' of 'unsymmetrical kidney' is about 1 in 2400 autopsies.

The actual number of genuine cases recorded is a matter of considerable doubt, and will always remain so, in consequence of the ambiguity of many of the older and some of the more modern writers. Still, various authors, as Rayer (22), Mosler (16), Beumer (2), Morris (15), Ballowitz (1), have collected from the literature accessible to them such cases as they considered to belong to this category, and formed generalisations which have differed very materially with the number of cases examined. In the most recent of these monographs, that of Ballowitz, 213

cases, including three of his own, are tabulated and analysed, and references are given to 25 additional cases which were inaccessible to the author. Of the latter, I have been able to consult the original records in five instances only, viz., those of Taylor (27), Golliday (8), Gouley (9), Hutchison (11), and Thacker (29) (2 cases); in addition to these, however, several cases have been recorded since the publication of Ballowitz—by Rossi (24), Galt (7), Newman (17) (2 cases), Sutherland and Edington (26), and White (33). This gives us, then, if we include the present case, a total of 226 cases of 'unsymmetrical kidney.' An analysis of these cases points to the following conclusions.

Age.—Cases have been met with at all ages up to 81 years, the majority in individuals of middle age. It would thus appear that the condition *per se* exerts but little influence on the duration of life.

Sex.—The condition is almost twice as common in males as in females—120 : 71.

Side.—The frequency with which the defect is met with on the two sides varies considerably in the two sexes. In males, renal aplasia is more common on the left side than the right,—76 : 44. In females, on the other hand, the two sides have about the same frequency,—left 31, right 35.

Irrespective of sex, renal aplasia is more common on the left side.

I. CONDITION OF THE EXISTING KIDNEY AND THE STRUCTURES IN RELATION TO IT.

Situation.—In the majority of cases, the existing kidney was present in its normal situation. It has been found in the true pelvis (4 cases), at the pelvic brim (2 cases), in the iliac fossa (3 cases), and slightly displaced in the loin, either upwards or downwards, (2 cases). Perhaps the most interesting example of displacement is that recorded by Förster (6), where the existing left kidney had become transported into the right loin; its ureter, after passing behind the colon, entered the bladder on the left side.

Size.—Compensatory enlargement is an almost constant feature. In a few of the records it is stated that the kidney was normal in size (28 cases, including 4 diseased specimens), or smaller than normal (5 cases), but in none of these cases are

actual measurements or weights given. In the majority of cases the dimensions of the existing kidney are recorded as 'enlarged,' 'twice the normal size,' etc., but in some 40 instances definite dimensions or weights or both are given, and among these there is not a single instance in which the kidney did not exceed the normal, the smallest weight recorded, for the age of the subject, of an 'unsymmetrical kidney,' apparently not diseased, being 198 grammes in a male æt. 48, *i.e.*, about half as much again as the normal weight. In the subjects whose age varied from 20 years upwards, the recorded weights varied between 200 grammes and 440 grammes, averaging about 290 grammes: these, of course, include several diseased specimens, whose weight was abnormally great.

The cause of this compensatory enlargement, whether it depends on hyperplasia or hypertrophy, or on both, has been the subject of many investigations. Among the examples of 'unsymmetrical kidney' which have been examined from this standpoint, hyperplasia of the renal elements was found in all, and in some, hypertrophy in addition—(Beumer (2), Guttmanu (10), Falk (5), Leichtenstern (12), Eckardt (4), Palma (19), and Welch in Polk's case (21).

A correct estimation of the latter must, however, owing to the fallacies with which cellular measurements are beset, be extremely difficult to obtain.

Shape.—In a few instances the kidney has been described as 'more rounded,' 'globular,' 'lobulated,' or 'quadrilateral,' but in the vast majority the shape presented but slight deviation from the normal.

Vessels.—As a rule, the renal vessels presented no abnormality beyond some slight increase in calibre; in some cases, however, there were two or three arteries from the aorta, or in displaced kidneys the vessels were derived from the common iliac or middle sacral artery (1 case).

Ureter.—Like the vessels, the pelvis and ureter in the great majority of cases presented nothing abnormal beyond a certain increase in size and calibre; below, the ureter entered the bladder in the usual situation. In a few cases, interesting deviations from this condition are recorded. Morgagni (14) describes a case of Valsalva's, in which the left kidney and ureter were

absent, whilst the right kidney, which was double the normal size, was provided with two pelves and two ureters, both opening into the right side of the bladder ("Ureter autem uterque ad dexteram tendebat vesicæ partem"); a condition almost certainly depending on the association of two kinds of malformation, viz., unilateral aplasia, with complete duplication of the ureter and pelvis on the opposite side, and not on fusion. In Förster's case already mentioned, transposition of the existing kidney gave rise to the at first sight puzzling arrangement of the ureter of a right kidney opening into the left side of the bladder. Again, in one or two cases the ureter is said to have entered the bladder nearer the median line than usual.

Supra-renal Capsule.—With very few exceptions, this organ was normal in size and position.

II. CONDITION OF PARTS ON THE DEFECTIVE SIDE.

Kidney.—In all cases absence of the kidney is recorded. A few observers mention the existence of some connective tissue in the situation of the kidney, but have never found it to contain any rudiments or remnants of renal tissue. In a case recorded by Ogston (18), and about which there is considerable room for doubt as to the validity of classing it among the cases we are now dealing with, a cyst was attached to the lower end of the existing kidney, from which a ureter could be traced to the opposite side of the bladder. It seems probable that in this case one has to do with a misplaced and extremely hypoplastic kidney, yet it was associated with unilateral absence of the genital passages and ovary on the same side.

Vessels.—In fifty-nine instances it is stated that the vessels were quite absent, in seven that they were represented by minute vessels, and sometimes by thin fibrous cords, running to the adjacent lymph glands and fat. In the other cases no mention is made of the condition of the vessels.

Ureter.—The condition of the ureter in many instances is unfortunately not definitely recorded; in the majority, however, it is stated to be absent, and in 16 cases only, to be present in a more or less rudimentary form, consisting then of a fibrous cord, pervious for a variable extent at its vesical extremity, and

ending at its renal end in a cyst, or in finger-like diverticula, or more often gradually merging into the adjacent connective tissue. In other cases it was found to be represented by a small cul-de-sac of the bladder-wall in the situation of the ureteral opening, and in one case the rudimentary ureter and vas deferens were united close to the bladder, and were connected with that viscus by a short common duct, which, however, in consequence of being impervious, had become dilated into a cyst projecting into the cavity of the bladder.

When quite absent, then the ureteral orifice was also absent, and in some cases the plica ureterica on the same side.

Supra-renal Capsule.—Mention is made of this structure in 115 instances, as being absent in 32 and present in 83. When present, it almost invariably occupied its normal position, but in a certain number of cases—14—it presented slight variations in form and size, sometimes being enlarged, sometimes diminished; and in one case was represented by four separate nodules, united by loose connective tissue (M. Brown (3)).

The Bladder.—In a few cases asymmetry of the bladder has been noted, depending on defective development of the side corresponding with the renal defect. The absence of ureteral orifice and of plica ureterica has already been mentioned.

The Prostate.—Only a few observations are recorded in which there was prostatic asymmetry as in the present case.

Associated Malformations.—In 75 of the 226 cases, i.e. 33 p.c., more or less extensive congenital defects of the genital organs are recorded. Of these 75 cases, 29 were males and 42 females, whilst in 4 the sex was undeterminable.

As Ballowitz suggests, it seems very probable that the frequency of malformations of the male genital organs in association with 'unsymmetrical kidney,' as indicated by the above figures, is underestimated, owing to the comparative infrequency with which those organs are examined in the course of an ordinary post-mortem.

In males, absence of the vas deferens, vesicula seminalis, and ejaculatory duct on the same side has been met with most frequently; in some of these cases there was a rudimentary or atrophic condition of the testis on the same side, but only in a few was complete absence of the genital gland observed.

In females, among the various malformations met with, uterus bicornis occurred most commonly, then septate uterus along with duplication of the vagina, uterus unicornis, absence of Fallopian tube, absence and atrophy of ovary, and in Polk's case complete absence of uterus and vagina was found.

GENERAL CONSIDERATIONS.

Regarded from a general standpoint, all these cases agree in the complete absence of one kidney, associated with a complete or partial absence of the corresponding ureter and vessels, and in some cases also with varying manifestations of defective formation of the genital ducts and glands on the same side; whilst on the opposite side the most striking feature is the constancy of the compensatory enlargement of the existing kidney.

In endeavouring to determine the exact nature of such cases, three possibilities have to be considered, viz., complete absence or extremely rudimentary development (aplasia); arrested development at a later and still rudimentary stage (hypoplasia); and lastly, secondary atrophy—that is, atrophy occurring after the termination of foetal development.

Many cases, viz., those in which there is complete unilateral absence of kidney, vessels, and ureter, may without doubt be relegated to the group of aplasia. In the 16 cases, however, in which a more or less rudimentary ureter is described, it is not in every case easy to determine whether one has to do with arrested development or with secondary atrophy. In 6, where the ureter was represented by a small pouch or diverticulum of the bladder-wall, arrest of development seems the more probable explanation, but in the remaining 10 cases there is no criterion for either one decision or the other.

Lastly, there are a considerable number of cases in which no mention at all is made of the condition of the ureter, and these must ever remain invested with doubt.

As regards the cause of the malformation, this must, I believe, be directly related to defective vitality of the cells which should form in the natural course of events the Wolffian duct and its offset—the metanephric duct.

On comparing the condition of the parts which ultimately

develop from the Wolffian body and its duct (epididymis, vas) with the condition of those which develop from the metanephric duct (ureter, pelvis, renal tubules), one can form a series in which the indications of arrest of development at various phases in the formation of these structures is very evident. At one end of such a series there are the cases in which complete aplasia obtains of the Wolffian duct and that part of the body which normally persists as the epididymis, then come the great majority of cases in which the development of the Wolffian duct itself has proceeded, but has failed to give rise to the offset which would have eventually formed the metanephric duct: in other cases the metanephric offset is formed, varying from a mere rudiment to a fully formed duct, which has only failed in its final efforts at subdivision to form the renal tubules. Regarded in such a fashion, renal aplasia, in the narrower sense of the term, obtains throughout the series. Expressing this series in terms of the adult organs, an examination of the recorded cases shows that the vas deferens is present most frequently, that it is often present when the ureter is absent, that it is constantly present when there is the slightest indication of ureter, that its absence always implies a complete absence of the ureter.

The points showing the relation of the malformations to developmental sequence can only be demonstrated among the male cases, owing to absence of any records of the condition of the parovarium in the female cases.

In conclusion, it is hardly necessary to do more than mention the importance of 'unsymmetrical kidney' from the surgical standpoint, since this has been amply demonstrated in the well known cases of Polk (21) and Taylor (28), where a fatal termination resulted in one in consequence of the extirpation of an 'unsymmetrical kidney,' unfortunately misplaced, and in the other, in consequence of traumatic rupture of an 'unsymmetrical kidney,' which was unfortunately in its normal position.

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Note by Ed.—To complete the record of cases of asymmetric kidney I may add, that in the "Anomaly Book" kept in the Cambridge dissecting-room there is a record of the absence of the right kidney in a male subject, in the Lent Term, 1891. In this case there was no right ureter, but no anomaly of the vas deferens. The left kidney was enlarged, but no record was kept of its weight. Reference may also be made to a specimen showing absence of the left kidney and its vessels associated with uterus unicornis. Described and figured by W. Turner in *Edinburgh Medical Journal*, 1865.

RUDIMENTARY CLAVICLES AND OTHER ABNORMALITIES OF THE SKELETON OF A WHITE WOMAN. By ROBERT J. TERRY, M.D., *Demonstrator of Anatomy in the Missouri College of St Louis, U.S.A.*

THE skeleton about to be described was prepared some twelve years ago by Dr Charles Todd, then Professor of Anatomy in the Missouri Medical College in St Louis.

No history could be obtained of the subject before her death, except that she was an inmate of the county poorhouse.

Dr Todd recorded the finding of several irregularities of the skeleton, among them the rudimentary condition of the clavicles, in the *St Louis Courier of Medicine*, but I think no full account has ever been made of this extremely interesting case.

The subject was small in stature, *apparently* very aged, and peculiarly deformed; and the bones, when being cleaned, proved to be so light and brittle that great care had to be exercised to prevent breakage, which did occur in the shaft of the right femur.

The most noticeable deviations from the normal are confined almost entirely to the axial skeleton, and to the pectoral girdle and pelvis,—some seemingly due to old age, some to disease, and others the result of an irregular development.

Since it is my intention merely to report the anomalies present, I shall enumerate them as I find them in the various regions, whatever they may have resulted from, beginning with the examination of the skull

Looked at from *above*, the cranium is broad and the zygomata are hidden from view. A metopic suture, faint below, opens into a wide fissure with irregular margins, which occupies about the middle two-fourths of the space between the nasion and bregma. The frontal eminences are well rounded, the left a little more prominent than the right. There are two parietal foramina, situated very near the sagittal suture and in a slight depression. On this upper aspect may also be seen on each

side an antero-posterior suture, which divides the parietal bone into upper and lower parts of nearly equal size. About the middle of the sagittal suture are two small Wormian bones.

There is marked parieto-occipital flattening on the left side, and this aspect of the cranium gives the impression of having been shoved forward, there being present a corresponding discrepancy in the meeting of the right and left halves of the coronal suture

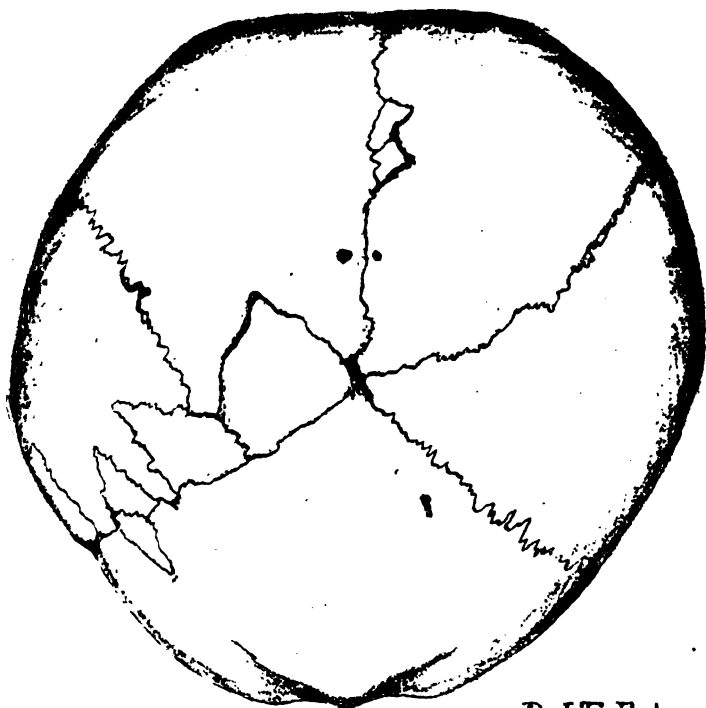


FIG. 1.—Norma occipitalis. (3.)

at the middle line, and the bulging of the frontal eminence of the left side already mentioned.

A broad and shallow groove runs for a short distance transversely in front of the middle of the coronal suture.

When the skull is placed base downward and viewed from the *side*, it is seen to rest behind upon the occipital bone, posterior to the foramen magnum, quite a bulging downward

of the bone occurring at this place. In front it rests upon the one remaining tooth of the maxilla, which projects downward from it.

The lower parietal bone is marked at its antero-inferior angle by a slight temporal line, and it articulates anteriorly with the frontal bone, and below with the squamous part of the temporal.

Both squamous and mastoid portions are very small, the former showing itself as much on the under surface of the cranium as upon the side of it.

The mastoid process is rudimentary, and measures 10 mm. in length. Between the three parts of the temporal bone are sutures more or less distinct, and the mastoid part is in places quite separate from the squamous portion.

The zygomatic arch is incomplete, an interval existing between the temporal process of the malar bone and the overhanging blunt end of the zygomatic process.

The greater wing of the sphenoid, deeply placed, articulates with the malar, frontal, and squamous bones. This part of the sphenoid is separated from the antero-inferior angle of the parietal by the distance of 30 mm., the length of the fronto-squamous suture.

The description given above for the lateral aspect applies to both sides of the skull; on the left side there are, in addition, several large Wormian bones in the parieto-squamous and parieto-occipital sutures.

There is nothing unusual to be seen on the *back* of the skull except the meeting at the lambda of the sagittal, lambdoid, and the two intra-parietal sutures.

The skeleton of the *face* presents some interesting points. It is low (index, complete facial, 71.42). The orbits are large, high, and nearly square; the area between them formed by the nasal processes of the maxillæ and the nasal bones is but slightly convex from side to side, and nearly straight from above downward. There is scarcely a concavity between the glabella and nasal bones, and the distance from side to side measures from one internal angular process to the other 29 mm. The nasal bones are very short (9 mm.), and the anterior nasal aperture high and four-sided. Between the lower margin of this opening and the under surface of the hard palate in the median line the

thickness of the bone is reduced to 3.5 mm. The vomer is absent.

On the *under* surface the incisor sutures are visible, the anterior palatine foramen large and irregular in outline, and the posterior nasal spine bifid. Owing to the absence of the alveolar arch, it is difficult to say whether the palate was flat or arched; the outline of the indications of an arch is elongated. Both the pterygoid processes and greater wings of the sphenoid are small and poorly developed. Measuring from the basion to the post-nasal spine the distance is 32 mm. (basi-nasal length, 83 mm.), and this shortness, together with the abrupt ascent of the basilar process of the occipital bone, makes the guttural fossa appear unusually deep; this appearance is very striking, but deceptive, since I find the depth in proportion to the size of the other parts in this region to be normal.

The anterior wall of the carotid canal is absent, and the apex of the petrous bone is connected with the dorsum sellæ, as far as can be made out, by an ossified *petro-sphenoidal ligament*. Styloid processes broken and lost.

What appear to be the alæ of the vomer are large, rounded, and hollow.

A suture indicates the junction of the basi-occipital and the basi-sphenoid, and this shows at its middle a minute foramen leading upward about 4 mm.

The foramen magnum is elliptical; the occipital condyles convex antero-posteriorly, but flat from side to side.

The hard palate measures from the mid-point in the position of the alveolar arch in front to the base of the post-nasal spine 42 mm., and in width 44 mm.

Jaws and teeth.—In both jaws the alveolar processes are absent. The mandible is large, and projects some distance in front of the maxilla. The articular surfaces of the condyles are rough and irregular, and each is separated from the slender coronoid process by a narrow sigmoid notch (12 mm.), which received the articular eminence of the temporal bone.

The tip of the coronoid touches the squamous part of the temporal, here marked by a slight fossa. On the right side in the deep groove, at the lower part of the ramus of the mandible, a molar tooth is partially exposed as it lies em-

bedded in the bone, and in the body of the mandible in the region of the mental foramen of the left side two teeth are just visible.

One large cuspidate tooth projects downward from the maxilla on the right side, the crown of which is worn, and in front of this another tooth of a similar shape is present, partly lodged in the bone and resting on its labial side.

These two last-mentioned teeth are just external to the incisor suture of the right side.

Being a natural skeleton, the presence of ligaments and periosteum obscures in great measure the individual bones of the spine, but of the parts exposed there seems to be nothing irregular. However, there are lateral curves in the dorsal region, an upper one (2nd, 3rd, 4th, and 5th bones) convex to the right, and a lower curve, also convex to the right (10th, 11th, and 12th bones). The lumbar spine in its lower part is convex to the left.

The dorsal curves are very sharp, but the lumbar curve is slight.

The compensation of these curves is, to the original primary curve (whichever it may be), such as to maintain the trunk in a tolerably erect attitude.

The ribs are twelve pairs; the eighth costal cartilage reaches the sternum. The latter consists of six pieces—a manubrium, a gladiolus subdivided into four parts, and an ossified ensiform appendix.

The thorax, as a whole, is normal in contour, except in the upper part of the right side: here it has suffered compression, and the superior opening of the thorax has been made unsymmetrical.

The pectoral girdle.—The clavicle of each side is deficient in its acromial half or more. Each bone is a slender spicule, compressed from before backward, arched a little from end to end, convex forward, and the sternal end thicker than the acromial end. Each is joined firmly by ligament to the sternum in the usual place, and fastened to the first costal cartilage by a rhomboid ligament. The acromial end is connected by a fibrous band both to the acromion process and the coraco-acromial ligament on the left side, and to the coraco-acromial ligament alone on the

right side. The right clavicle measures 47 mm. in length, 5·5 mm. in antero-posterior diameter at its sternal end, and 3·5 mm. at its acromial end. The left bone is 49 mm. long, 5 mm. in diameter at its inner end, and 3 mm. at its outer extremity.

Both acromial processes are ununited to the scapular spine. The rest of the scapula is so covered by fascia and periosteum as to be concealed almost completely.

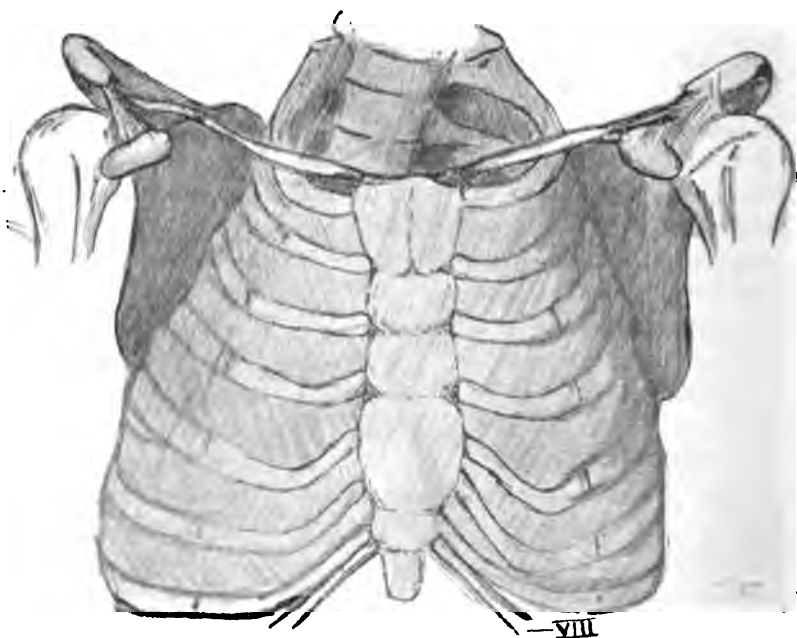


FIG. 2.—Front of chest, to show rudimentary clavicles and sternum.
(Less than $\frac{1}{2}$.)

Pelvis.—The pelvis is *high* and *laterally compressed*. The inlet is of the shape given in the drawing; the projection forward and downward of the anterior part (*a*) is very marked. The ilia are almost vertical, and the crests are ununited. The obturator foramina are small and rather triangular. Both the pubis and ischium of the two sides are small in proportion to the ilia, and appear poorly developed.

The right acetabulum has suffered from the effects of a fracture of the neck of the right femur. The sacrum consists

of five bones; the bodies of the first and second and second and third are united by ligaments, judging from the grooves which are visible on the anterior aspect between these bones, and which are filled by some soft material.

A sharp bend occurs at the level of the third sacral bone, so that the lower part of the sacrum makes with the upper part an

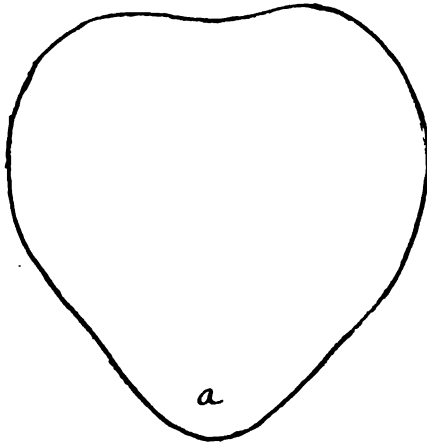


FIG. 3.—Outline of pelvic brim. ($\frac{1}{2}$.)

angle of something less than 90° . The coccyx consists of four separate bones.

The humeri are well-proportioned sound bones, the lower articular surfaces only appearing to have been somewhat roughened by trouble in the elbow joint. The shaft of each femur is very slender. The right bone has had a fracture of the neck, as already mentioned, which has united by bone so far below its normal place as to have caused a shortening of about 40 mm. of the limb. This shortening is also increased by the tilting of the pelvis referred to above, *upward on the right side*. The forearms and hands and legs and feet are missing.

Table of Measurements.

Glabello-occipital length,	174 mm.
Basi bregmatic height,	118
<i>Vertical index</i> ,	67·81
Greatest parieto-occipital breadth,	151
<i>Cephalic index</i> ,	86·78
Length of foramen magnum,	39
Basi-nasal length,	83
Inter-zygomatic breadth,	112
Nasio-mental length,	80
<i>Complete faciel index</i> ,	71·42
Nasal height,	41
Nasal width,	22
<i>Nasal index</i> ,	53·65
Orbital width,	32
Orbital height,	40
<i>Orbital index</i> ,	125
Nasio-alveolar height,	44
<i>Upper facial index</i> ,	39·29
<i>Lower Jaw—</i>	
Symphysial height,	12
Coronoid height,	61
Condylod height,	49
Genio-symphysial length,	77
Intergonial width,	80
Breadth of ascending ramus,	24
<i>Pelvis—External dimensions:</i>	
Breadth of pelvis,	198
Height „	185
<i>Breadth height index</i> ,	93·43
Subpubic angle,	65°
Dimensions of cavity of pelvis:	
Transverse diameter of brim,	108
Conjugate „ „	108
<i>Pelvic index</i> ,	100
Oblique diameter of brim, right,	115
„ „ left,	110
Length of sacrum,	86
Breadth „	99
<i>Sacral index</i> ,	115·11

SUMMARY.

A reference to the vertical and cephalic indices shows the cranium to be flat and broad, the vertical index of 67·81 placing it in the tapeinocephalic group, and the cephalic index, 86·78, among the brachycephalic crania.

Of the cranial sutures that are commonly present in adult life, all are open in this case except the fronto-nasal. Others present are: a metopic suture, an antero-posterior intra-parietal suture on each side, the transverse suture between the basi-sphenoid and the basi-occipital, and sutures, more or less complete, between the three parts of the temporal bone.

The face is platyrrhine (nasal index 53·65) and megaseme (orbital index 125).

The whole face low (complete facial index 71·42). The upper facial index of 39·29, in the absence of the alveolar arch, would seem to place the skull in a class not to be compared with skulls having an alveolar arch. However, I have measured from the nasion to a point in the middle line where the alveolar arch would be, and compared this diameter with the inter-zygomatic, with resulting index of 39·29. It may be that the *maxilla has never had an alveolar arch*, and the low index obtained may represent the proportion which has always existed in this case.

It will be noted that the area of origin of the muscles of mastication is small and defective. When the coronoid processes of the mandible touch the temporal bones, the body of the jaw is nearly horizontal, and a gap exists between the jaws, which can be diminished by making the lower jaw pivot upon the tips of the coronoids in the shallow fossæ of the temporal bones already referred to, and causing the condyles to glide forward over the articular eminences of the temporal bones. In fact, these eminences and the condyles themselves are correspondingly worn away.

The muscular area of the occipital bone is poorly marked (and the mastoid process small), but on the humeri the deltoid and pectoral areas of attachment are well marked.

The slight lumbar curve in the spine corresponds both in

direction and degree to the pelvic tilting, but the latter condition seems to have no relation to the shortened right limb.

It is impossible to tell how many of the sacral vertebræ are separate; but on account of the sharp bend, and the fact that the sciatic ligaments are relaxed, it would appear that there was here a movable joint, and that the sacrum was bent at that place during the preparation of the skeleton, and subsequently dried so.

I have to thank my cousin, Dr Todd, for his kindness in allowing me to use the skeleton in making these notes.

ON THE 'LEVATOR ANI' OR ISCHIO-ANAL MUSCLE
OF UNGULATES, WITH SPECIAL REFERENCE TO
ITS MORPHOLOGY. By PETER THOMPSON, M.B., Ch.B.,
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Manchester.*¹

THE object of this communication is to show that the so-called levator ani of ungulates is an entirely different structure from the muscle bearing the same name in man and anthropoid apes. In point of fact, the levator ani does not exist in ungulates, and the muscle so designated should be called, as indeed it is by veterinarians, the ischio-anal muscle.

As long ago as 1845, Straus-Durckheim pointed out that the levator ani of man corresponded to two tail muscles present in carnivores, viz., the ilio-caudal or ilio-coccygeus, and the pubo-caudal or pubo-coccygeus, and considerable additions to our knowledge of the anatomy and morphology of the caudal muscles have subsequently resulted from the observations of Eggeling on marsupials, of Kollmann on tailed apes and anthropoids, of Lartschneider on carnivores and primates, and of Holl on the muscles of the pelvic outlet in man.

The levator ani, as it exists in man and some primates, is not present in lower mammals, though the homologous muscles can usually be recognised without difficulty. In most cases where observers refer to the levatores ani in lower mammals, the descriptions given, except perhaps in ungulates, are those of two muscles which pass to the tail without coming into direct connection with the rectum. Take, for example, the descriptive accounts by Ellenberger and Baum of the levator ani in the dog, and by Miller in the seal. In them we find details of two muscles whose origin from the pelvic wall and insertion into the caudal vertebræ leave no doubt as to their real nature.

Clearly then, two muscles in lower mammals, the ilio-coccygeus and pubo-coccygeus, correspond to the levator ani in man. They are attached to the inner aspect of the lateral wall

¹ Read at the Meeting of the Anatomical Society, November 1898.

of the pelvis, the ilio-coccygeus to the neighbourhood of the ilio-pectineal line or immediately below it, the pubo-coccygeus to the back of the pubis, and each is inserted into the proximal caudal vertebræ. At the most, any action which they exert on the rectum is limited to lateral compression, and is quite secondary to that of moving the tail. Both the ilio-coccygeus

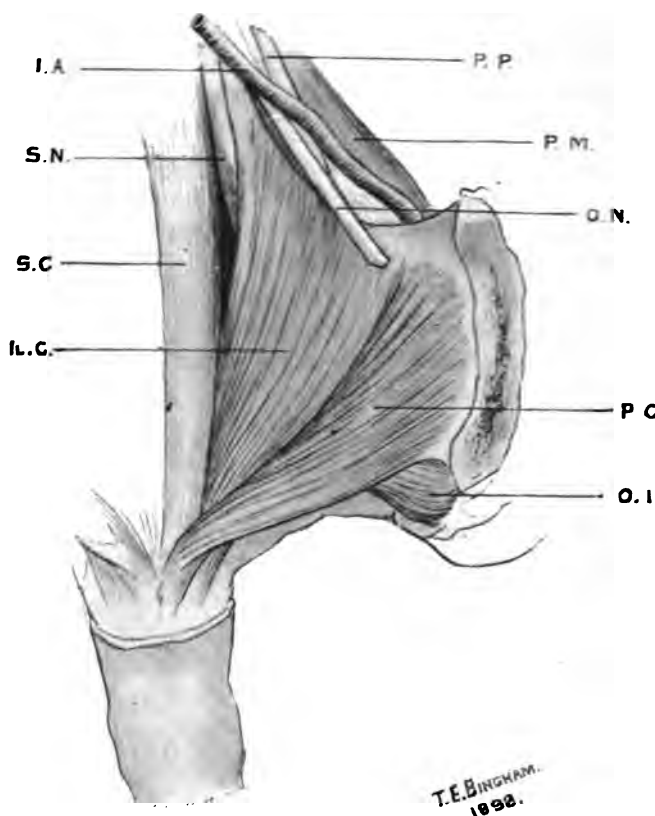


FIG. 1.—Flexor muscles of the tail in a monkey (*Macacus rhesus*), left side from within; P.P., psos parvus; P.M., psos magnus; O.N., obturator nerve; P.C., pubo-coccygeus; O.I., obturator internus; h.C., ilio-coccygeus; S.C., sacro-coccygeus; S.N., sacral nerves; I.A., iliac artery.

and pubo-coccygeus are the result of a lateral extension on to the side wall of the pelvis from a single powerful flexor of the tail situated on the ventral aspect of the sacral and caudal vertebræ.

In the majority of mammals, the ilio-coccygeus and pubo-coccygeus are similarly arranged. Even in man, in whom, in consequence of the retrogression of the caudal vertebræ and the assumption of the erect posture, the greatest modifications are evident, the primitive arrangement of two muscles passing from the side wall of the pelvis to the rudimentary coccyx is retained to a remarkable extent (fig. 3). In man, however, they are modified to effect the more efficient closure of the pelvic outlet, and to support the superimposed viscera. It is interesting to find that some anatomists recommend the discontinuance of the name 'levator ani' entirely, and the substitution of the terms 'ilio-coccygeus' and 'pubo-coccygeus.'

In ungulates, however, this general arrangement is not adhered to. From dissections of the camel, cow, bull, mare, and stallion, I have satisfied myself, so far at least as these animals are concerned, that neither the ilio-coccygeus nor the pubo-coccygeus are present; and inasmuch as the levator ani is admittedly only a specially modified form of these muscles, it is obvious that there is no morphological equivalent of the levator ani in the ungulates referred to.

In the camel, which may be taken as a type, there are two muscles which arise in close apposition from the internal surface of the ischium, but they are morphologically distinct from both the ilio- and pubo-coccygei. One, arising close to the spine and passing to be inserted into the caudal vertebræ, is dorsal in position, the other, arising close to the thyroid foramen, is ventral; the ventral muscle passes along the lateral aspect of the rectum, to terminate in short tendinous fibres in its walls near the anus. At its insertion the fibres intermingle with the deeper layers of the external sphincter ani, and none are attached to the caudal vertebræ.

There can be no doubt that the dorsal muscle is the ischio-coccygeus or abductor caudæ, but the significance of the ventral muscle, which, from its attachments, is well named ischio-anal, seems to have been misunderstood. By most observers it is regarded as corresponding to the levator ani, and if this is so, the question naturally arises,—To which of the flexor tail muscles does it correspond, the ilio-coccygeus or pubo-coccygeus, or does it represent both?

Apparently, observers do not agree upon this point. Holl, who has found a similar disposition of the two corresponding muscles in the horse and roebuck, is of opinion that the dorsal

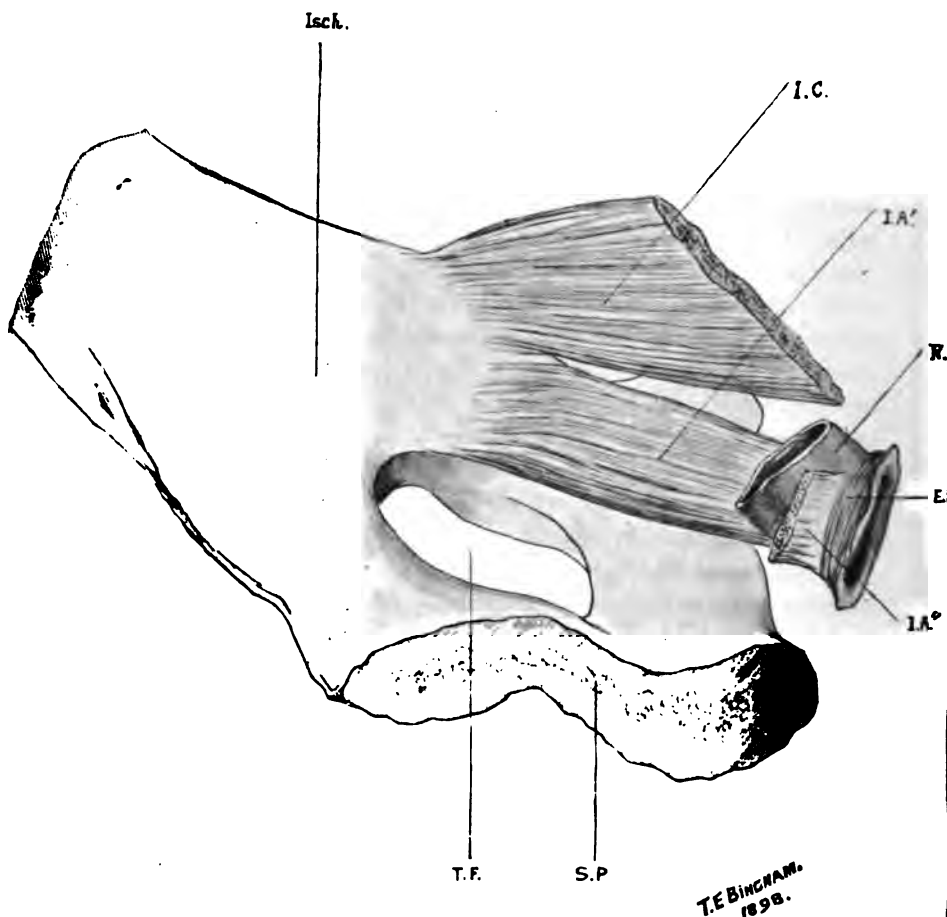


FIG. 2.—Ischio-anal and coccygeus muscles in the camel (*Camelus dromedarius*). Isch., ischium; I.C., ischio-coccygeus passing to be inserted into the caudal vertebrae; I.A' and I.A'', ischio-anal muscles of the two sides; R., rectum; E.S.A., external sphincter ani; S.P., symphysis pubis; T.F., thyroid foramen.

muscle is the ilio-coccygeus, and the ventral muscle the pubo-coccygeus. He thinks this view is not unlikely, because in the rabbit and guinea-pig the origin of the ilio-coccygeus is trans-

ferred to the mesial surface of the ischium, in the region of the spine. It may be pointed out, however, that the descent of the attachments of the flexores caudæ on the lateral pelvic wall does not appear to influence their insertion into the caudal vertebræ. In the rabbit, guinea-pig, and even in man, although the transference of the pelvic attachment has undoubtedly taken place, the connection of the muscles with the vertebral column is still retained.

Lartschneider, after examining the horse and stag, came to the conclusion that the dorsal muscle was the ischio-coccygeus, and that the ventral muscle was the homologue of the pubo-coccygeus of the rabbit and edentates. But Holl has shown that what Lartschneider regarded as the pubo-coccygeus in the rabbit was a part of the sphincter cloacæ. Lartschneider commenced with this observation in tracing the phylogenetic history of the pubo-coccygeus, and he believed that the pubo-coccygeus of edentates, and indeed of mammals generally, was derived, like the sphincter cloacæ, from the great skin muscle (*M. cutaneus maximus*). Holl has shown that this view is untenable, and that the pubo-coccygeus of the rabbit and edentates is, like the corresponding muscle in other mammals, an extension of the tail musculature.

Lastly, Paulet, writing on the comparative anatomy of the perineum, states that the ischio-anal muscle in the stag is homologous with the levator ani of man, but that they differ in form. He regards the ischio-anal muscle as corresponding only to a limited part of the levator ani, viz., to that which remains if the fibres arising from the pubis and obturator fascia be removed. It is noteworthy that Paulet, whilst holding this view, was struck with the close resemblance of the ischio-anal muscle in the stag, cow, and horse.

Thus, whilst Holl, Lartschneider, and Paulet disagree as to the precise homologies of the ilio- and pubo-coccygei, and differ particularly as regards the extent to which they are represented in the 'levator ani' of the ungulates examined by them, they are apparently in accord in stating that the "levator ani" represents one or other of the two flexor tail muscles, either wholly or in part. A careful consideration of (1) the attachments and (2) the nerve-supply has convinced me that this view is probably incorrect.

There is no resemblance between the attachments of the pubo-coccygeus of other mammals and the ischio-anal muscles of ungulates. No fibres of the latter arise from the pubis, and none pass to the caudal vertebræ. I have examined specimens of monotremes, marsupials, carnivores, rodents, insectivores, and primates, and in all the pubo-coccygeus never failed to exhibit in some degree its primitive attachments. Invariably the muscle took origin either from the back of the symphysis, from the body of the pubis, or from the horizontal ramus of the pubis. Similarly, with regard to its insertion, fibres could always be traced either to the bodies or transverse processes of the proximal caudal vertebræ. Nevertheless, Lartschneider, whilst admitting that no fibres are attached to the vertebral column, believes that the ischio-anal muscle represents the pubo-coccygeus of edentates, marsupials, carnivores, and primates, and that its peculiarities depend on the size of the body and the mode of nutrition of the animal.

It should be mentioned here, that in the cow some of the fibres of the ischio-anal muscle do not pass into the walls of the rectum, but unite with the fascia of the tail. Lartschneider has noted a similar arrangement in the stag and horse. I shall refer to the significance of these fibres subsequently.

Again, with reference to the possible correspondence of the ischio-anal muscle to the ilio-coccygeus. The latter muscle is always inserted into the caudal vertebræ. As to its origin, it must be admitted that this does not always take place from the ilium. The attachment may descend on the side wall of the pelvis, and the muscle then arises from the ischium as in the rabbit and guinea-pig, according to Holl, or from the fascia obturatoria as in man.

From the attachments, therefore, we may reasonably conclude that the ischio-anal muscle of ungulates corresponds neither to the pubo-coccygeus nor to the ilio-coccygeus of other mammals. Moreover, its direct connection with the rectum suggests that it should be included with the external sphincter and in the group of extrinsic rectal muscles.

The considerations of nerve-supply lend additional support to this conclusion. The importance of including the nerve-supply of a muscle in the consideration of morphological questions is

recognised by all observers. Quite recently, Dr Mall, in a paper on the "Development of the Ventral Abdominal Walls in Man," says on this subject, "that the studies in comparative anatomy by Gegenbaur, Huxley, and Kollmann have proved almost beyond doubt that nerve and muscle are associated with each other in the earliest stages of development, and that comparison of muscles can be made satisfactorily only when their nerve-supply is included." According to his views, "the history of a muscle is indicated by its nerve, and in studying the development of a muscle our main guide is its nerve." On the other hand, Professor Cunningham has shown that nerve-supply "is not an absolutely infallible guide."

As already mentioned, the ilio- and pubo-coccygei are simply differentiated parts of a single powerful tail muscle, which we may now refer to as the sacro-coccygeus, situated on the ventral aspect of the sacral and caudal vertebræ, and it is particularly interesting and significant to note that in monotremes and some marsupials, the three muscles are not distinct from one another. Whilst, however, there is no clear separation of the three constituent elements, they are easily recognisable, and the whole group appears as a flat muscular sheet passing from the side wall of the pelvis to the tail. This continuous sheet receives a continuous nerve-supply. The sacro-coccygeus is innervated by twigs from the sacral plexus, and the laterally extended differentiations of ilio-coccygeus and pubo-coccygeus respectively carry with them their nerve-supply from the same source. This holds good also in those animals in which the individual muscles of the group are more or less completely separated from each other. I have, indeed, found no exception in the animals I have had the opportunity of dissecting, but I note that Leche describes the ilio-coccygeus in *chrysochloris* as being supplied by a branch of the oburator nerve.

The levator ani in man receives its nerve-supply partly direct from the fourth sacral, and the branches from this source enter the muscle on its pelvic surface. In addition, branches from the internal pudic are also distributed to it, and these pierce its external surface. This variation from the primitive type may perhaps be looked upon as an example of transference of nerve fibres from a familiar to an unfamiliar route. The transfer-

ence becomes intelligible if we remember that the internal pudic supplies the group of muscles derived from the primitive sphincter cloacæ, and that, as a result of the formation of a pelvic floor, two muscular layers have been brought into close apposition, viz, one consisting of modified caudal muscles—the levator ani, the other, the superficial perineal muscles. We have here an excellent illustration of what has been described as “the struggle for supremacy between two contiguous nerves supplying contiguous groups of muscles.”¹

In ungulates, the ischio-anal muscle is apparently always supplied by branches from the internal pudic nerve. Apart from my own observations, which support this statement, I find that Chauveau describes the ischio-anal muscle in solipeds as supplied by the pudic nerve, and A. M. Paterson and R. C. Dun have recently described the levator ani in the Indian elephant as receiving its innervation from the same source. In all the ungulates I examined, I failed to find any nerves passing direct from the sacral plexus to the ischio-anal muscle, and this attracted my attention the more since in other mammals, in which the ilio- and pubo-coccygei were present, nerve fibres from the sacral plexus direct were invariably found. On the other hand, a number of branches proceeded from the internal pudic nerve, and these supplied not only the ischio-anal muscle, but also the external sphincter ani.

The nerve associated with the primitive sphincter cloacæ is the internal pudic, and all the muscles which are differentiated from it derive their nerve-supply from the same source. And although, as illustrated by the innervation of the human levator ani, there is a tendency for the nerve to overstep its original limits and extend its territory, these invasions must be regarded as secondary, and they need not obscure the primitive arrangement.

The conclusion arrived at from a consideration of the muscular attachments—that the ischio-anal muscle corresponds neither to the ilio-coccygeus nor the pubo-coccygeus of other mammals—is thus supported by the further consideration of the nerve-supply of these muscles, and the fact that the ischio-anal muscle is innervated solely from the internal pudic affords

¹ *Vide* Cunningham.

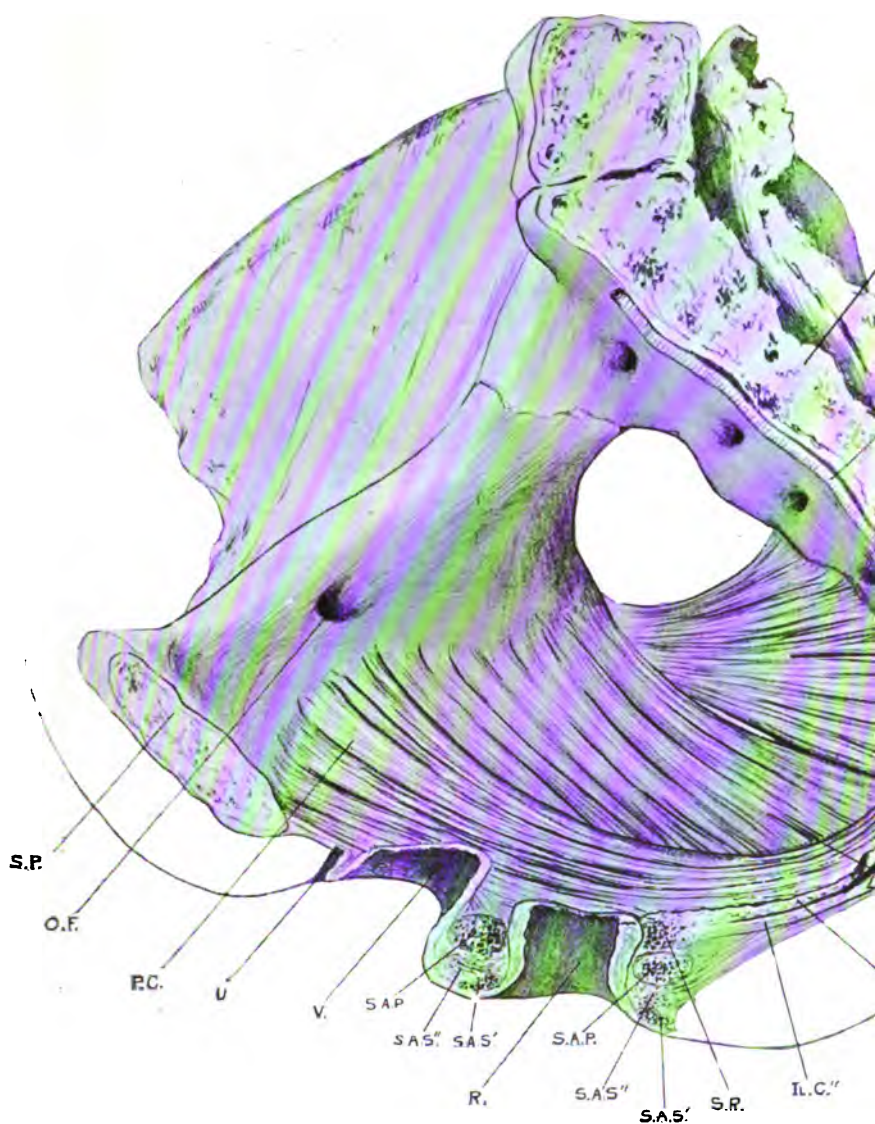


FIG. 3.—Sagittal section of the pelvis to show the pelvic diaphragm and external sphincter. M.S.A., middle sacral artery; L.S., ligamentum sacro-coccygeum anterius; I.C. coccygeal vertebrae; I.C., ilio-coccygeus; T.P.P.C., tendinous aponeurosis of puborectalis; S.R., sphincter recti; S.A.S', S.A.S'', sphincter cutaneous and superficialis; S.A.P., sphincter ani externus profundus; R., rectum; urethra; P.C., pubo-coccygeus; O.F., obturator canal; S.P., symphysis pubis.

additional evidence that this muscle should be associated with the anal sphincter and the other superficial muscles of the pelvic outlet.

I therefore venture to suggest that the ischio-anal muscle is not a tail muscle like the ilio-coccygeus and pubo-coccygeus, and that it cannot be regarded as homologous to them or to the modified levator ani. Its connections and nerve-supply show that it is probably derived from the primitive sphincter cloacæ, like the bulbo- and ischio-cavernosi. It has not, however, like these muscles, become attached to the circumference of the pelvic outlet, but has passed within its margin to the neighbourhood of the spine of the ischium, possibly, and at any rate the more easily, in consequence of the absence of the ilio- and pubo-coccygei muscles.

The connections between it and the other superficial perineal muscles are very intimate, and at once suggest a common origin. In the camel this is especially evident. The external sphincter ani encircles the posterior part of the rectum, and passes below into the bulbo-cavernosus. At the lateral margin of the continuous muscular mass two muscles are found on each side. Of these, one situated at the root of the penis is the ischio-cavernosus; the other, situated at the side of the rectum, is the ischio-anal muscle, and this extends upwards into the pelvic cavity, to be attached to the side wall, near the spine of the ischium.

The insertion of the fibres of the ischio-anal muscle into the fascia of the tail in the cow, stag, and horse finds an explanation if this view of the origin of the muscle be accepted. We know that the sphincter cloacæ is primarily attached to the under surface of the tail, and the caudal attachment is retained in ungulates, not only by the external sphincter ani, but also by the ischio-anal muscle.

The development of the ischio-anal muscle, and the peculiar course of its fibres, may possibly be explained by the behaviour of the rectum during defæcation. The muscle is specially developed in those animals in which protrusion of the rectal mucous membrane occurs during the expulsion of the fæces, and the function of the muscle is clearly to pull the anus forwards, and retract the protruded mucous membrane after the rectal

contents have been expelled. Hence the name 'retractor ani' which has, not inappropriately, been applied to it. Professor Sir William Turner has described the *retractores ani* in the dolphin, and remarks that from "the presence of this pair of muscles it is probable that the dolphin, like the horse, protrudes the anal mucous membrane in the act of defæcation, and the functions of these muscles is to retract it on completion of the act." Now, the attachments of the *retractor ani* in the dolphin closely resemble those of the *ischio-anal* or *retractor ani* in ungulates. In the former, the muscle arises from the pelvic bone, and ends in the muscular mass of the sphincter. Lartschneider regards the muscle in question in ungulates as a true *levator ani*, *i.e.*, a sling muscle of the rectum, but with this I cannot agree.

Since, then, the *ilio-* and *pubo-coccygei* muscles are apparently not represented at all in ungulates, one may in conclusion ask, What has determined their absence? To this question I am not at present prepared to give any definite answer. It may be due to the skeletal peculiarities, to the size of the body, or to the mode of nutrition. We know that in the herbivora the capacity of the intestinal canal assumes considerable proportions, and that this is largely dependent on the nature of the aliment. Their food contains a small proportion of nutritive elements, enclosed in an abundant matrix, so that they are compelled to ingest large quantities at short intervals. As the gastric and intestinal parts of the alimentary canal have been so profoundly modified to meet these special demands, there seems no reason why the modifications should not have extended to the rectum and the muscles in relation with it, though it is difficult to see why suppression of certain of the caudal muscles should have resulted.

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THE MORPHOLOGY OF THE MESENTERIAL DEVELOPMENT OF THE VERTEBRATE DIGESTIVE TRACT.

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A MESENTERY, in a general sense, consists of a duplicature of peritoneum whose blades, after embracing an organ, come in

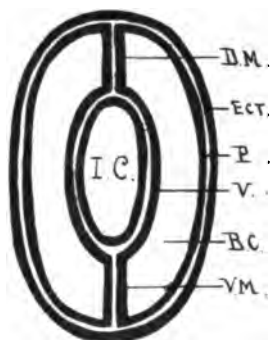


FIG. 1.—Diagram of the dorsal and ventral mesenteries. D.M., dorsal mesentery; V.M., ventral mesentery; Ect., ectoderm; I.C., intestinal cavity; B.C., body cavity (peritoneum); V., visceral, and P., parietal, layer of the split mesoderm (enclosing the peritoneal cavity).

contact with each other between the organ and the dorsal wall. In a strict anatomical sense, a mesentery consists of three distinct layers, viz., (a) A central essential structure, the *mesenterii membrana propria*, or the mesodermic mesentery. This is a connective-tissue membrane composed of nerves, blood- and lymph-vessels, connective and elastic tissue, and occasionally muscular fibres, such as Treitz's *musculus suspensorius duodeni*, or the muscles found in the ligamentum latum uteri. This is the real anatomic mesentery. (b) Each

side of this is covered by an exceedingly thin membrane (the peritoneum) composed of endothelial cells. This is the peritoneal mesentery, whose blades are the physiological (lymphatic) portions of the mesentery. Peritoneal duplicatures whose blades do not come in contact between the embraced organ and the dorsal wall do not in general constitute mesenteries; so while every abdominal viscus has a mesodermic mesentery, only certain of them have peritoneal mesenteries. The development of the mesentery, so far as is known, follows the same lines in all vertebrates. The dorsal mesentery of the digestive tract in its original form appears as a median plate, whose dimensions correspond with the size and length of the gut and its distance from the abdominal wall. The mesentery of the digestive tract must have relations to the form and size of the abdominal cavity, and the changing conditions of its viscera, *e.g.*, the varying size of the sexual organs, especially in fishes (as in the Lamprey—*Petromyzon*). If the digestive tract grows faster than the abdominal space it must assume curves and loops with consequent secondary changes in the corresponding mesentery, but these secondary changes do not influence its functions.

The race (phylogenetic) and individual (ontogenetic) peculiarities of mesenteries require original research from fish to man to comprehend their signification. It is suggestive to study the mesentery in fishes, because we find among them the typical perfect mesentery (Pike—*Esox*) and its complete absence (Lamprey—*Petromyzon*). While some fishes do not possess a mesentery, others appear to have a complete mesentery in early life, which partially disappears at a later period. In some adult fish such as yellow bass—*Roccus interruptus*—irregular atrophic defects may be found in both the dorsal and ventral mesentery of the tractus intestinalis: these vary in size from the diameter of a pea to that of an apple.

The examination of the peritoneum and mesenteries in fishes suggests the idea that the abdominal cavity was once filled with mesoderm, which has undergone a vast atrophy or shrinkage, leaving the viscera partially free, but covered with a thin remnant of mesoderm. It would appear that in early life, before food stimulated the intestinal mucosa, the blood supply

of the mesentery was amply sufficient to preserve it from atrophic defects. But when the food irritated the intestinal mucosa, so much blood was directed to it that it robbed the mesenteries of nourishment, and atrophy or defects appeared in that portion of the mesentery distant from large and constant blood supply. In higher vertebrates, where reduction and concentration of arteries becomes established, less irregular defects appear in the mesenteries, due to stretching both of mesodermic and peritoneal mesenteries, as *e.g.* the omentum majus and minus. The fish is sometimes the richest and sometimes the poorest in mesenteries; there may be so many that it is difficult to disentangle their relations, or no mesentery at all, whence arises the question of the utility of the peritoneum in the animal economy. Among fishes the relation of viscera and peritoneum are irregular. Not only do the mesenteries in different species vary, but also individuals of the same species differ within wide limits.

After the visceral plates fuse ventrally the animal body may be regarded as consisting of two tubes, one within the other: the inner of these is the alimentary canal, the outer is the body-wall. Our theme is to demonstrate the origin and development of the mesentery which dorsally suspends the inner or the digestive tube in the outer or the abdominal cavity.

At its first formation the digestive canal lies against the chorda dorsalis with which it was originally connected, and is held to the dorsal wall by a broad tract of embryonic connective tissue, the mesodermic mesentery, by which the right and left parts of the body cavity are separated from each other on the dorsal side. In this tissue may be found the two branches of the primitive aorta. The younger the embryo, the broader is this mesodermic mesentery. As the embryo becomes older, the tract of embryonic connective tissue gradually narrows and elongates. The alimentary canal slowly recedes from the chorda, elongating its connective-tissue bed, which by degrees narrows from side to side. The two original aortæ coalesce into a single trunk, locating itself between the chorda and intestine. In these early stages the mesentery can be seen to consist of the mesodermic connective tissue, in which blood and lymph vessels and nerves course to the digestive tract, and a right and left layer of flat endothelial cells.

The anterior ventral mesentery extends to the umbilicus in adults (human). In fish, the ventral mesentery may extend from stomach to anus. The tract of embryonic cells forming the base of the subsequent adult mesentery, Remak designated as the 'middle plate.' My researches have been made on the mesenteries of animals, chiefly chickens, sharks, pigs, amphioxus, squids, fish, turtles, ruminants, solipeds, dogs, guinea-pigs, rabbits, and frogs, but many beautiful specimens of human mesenteries have been studied, sufficient to demonstrate that the mesenteries of man and animals have developed in a precisely similar manner. Serial sections teach that the tract of cells forming the mesentery is a three-bladed structure, not uniform in thickness, and that it connects the whole length of the digestive tract to the vertebral column.

Early in life, as Toldt notes, the free surface of the mesentery is not in every locality covered by flat endothelial cells, but some parts may have cubical or cylindrical cells. The flat endothelial cell forms later, as the final permanent cell structure. The original broad tract of embryonal cells which is to constitute the future mesodermic mesentery appears simply as a neuro-vascular connective-tissue bed, which is covered on each side by endothelial cells. In this 'middle plate' tracts of connective-tissue fibres are deposited at a later period. A final change in arrangement of the mesodermic mesentery occurs late in intra-uterine life and after birth, owing to the deposition of fat in its meshes. Between the mesodermic mesentery and the endothelial layers on both sides there is a loose, delicate, subserous layer of connective tissue, by reason of which, in the adult, the *membrana mesenterii propria* can be easily separated from the endothelial layers. In the development of the mesentery, one must regard as the essential structure the mesodermic mesentery, because the endothelial layers are not essential, and in fact may be absent, as any one can satisfy himself by carefully dissecting the duodenum in adults. This gut in the adult appears to have no mesentery, because the right and left endothelial layers are absent, and its mesodermic mesentery lies with its right face in contact with the dorsal wall, almost entirely fixing the organ.

The left colon of man, normally, has no peritoneal mesentery,

because the blades of the peritoneum do not definitely come in contact with each other between the colon and dorsal wall, but it always has a mesodermic mesentery, containing its vascular and nervous supplies. The left colon has suffered the same change as the duodenum, except that the colon has lost but one (the left) endothelial layer, which was appropriated by the rapidly growing kidney and lateral abdominal wall. The same may be said of the right colon, except that the acquired developmental processes are more extensive and complicated than those affecting the left colon. By the separation of the layers of a mesentery, the organ becomes limited in motion, as in the case of the right and left colon and duodenum. In the omenta a somewhat different process occurs. The two endothelial layers persist, while the mesodermic mesentery almost, if not entirely, disappears, especially in the part of it which is equidistant from origin and insertion, or the point of greatest tension.

From the first appearance of the embryonal tract of cells on the middle dorsal wall to the completed mesenteries of the foetus, the complicated processes through which they pass consist in changes of relation of the three layers. These changes arise by elongation, by unequal growth and pressure of viscera, by appropriation, displacement, or coalescence of the peritoneal blades, and by the mesodermic mesentery becoming retro-peritoneal.

Such changes have practical applications in surgery. The cæcum, as it passes over the left face of the mesoduodenum, elevates and appropriates the left endothelial blade to cover itself; and the right face of the mesoduodenum, deprived of its peritoneal layer, is bound fast to the dorsal wall, fixing the duodenum in the shape of a spiral ring, which of course makes it deficient in peristalsis, and also the curve in the duodenum makes it much more difficult to force the food onward. The left face of the left mesocolon loses its left endothelial layer, and the mesodermic mesentery becomes firmly attached to the dorsal wall, from the median line to the external border of the left kidney. Thus the left colon is materially altered by the changes, both for function and surgery. The fixation of the left colon lessens peristaltic force, and in surgical procedures it suggests that we should never, if avoidable, tear through the

mesodermic mesentery, on account of possible injury to its vessels and nerves. Hence the left kidney should be attacked from the posterior side of the mesodermic mesentery and not in front, *i.e.*, the left colon should be pushed toward the median line before the kidney is attacked, so as to avoid wounding mesenteric vessels and nerves.

The changes brought about by coalescence or displacement of the endothelial layer during development of the mesogastrium are of less significance, both as to function and to surgery. This is inseparably bound up in the subject of the omentum majus.

Displacement or coalescence of certain parts of the endothelial membrane, aided by the projection of blood-vessels, induces the formation of retro-peritoneal fossæ, which are of considerable importance in surgery. These recessi peritonei may be the seats of hernia, especially the fossa duodeno-jejunalis, very rarely the fossa sigmoidea or fossa subcæcalis.

The mesodermic mesentery can be observed in sections of fœtuses before the third month, and appears to be made up of connective-tissue bundles along the mesenteric blood-vessels. At the third foetal month the 3-layered formation of the mesentery appears, and the endothelial layer on each side of the *mesenterii membrana propria* may be separated from it, as in the adult. The bundles of connective-tissue fibres in the middle layer are distributed along the blood-vessels—the highways of nourishment. Generally, an artery and vein lie imbedded together in the fibrous bundles. At the root of the mesentery, where the nerves and blood-vessels unite into large trunks, the mesodermic mesentery assumes a considerable thickness. Away from the large bundles of nerves and blood-vessels, the middle mesenterial layer becomes remarkably thin (even disappears by atrophy), as, for example, the middle of the omenta and in the region of the ileo-colic artery, where, owing to local atrophies of this and of the covering endothelium, apertures may occur.

When the mesodermic mesentery reaches the intestine, it suddenly expands and becomes thicker to distribute numerous fine fibres, muscles, nerves, and vessels to the gut-wall. In the fourth foetal month the layer formation of the mesentery becomes more pronounced; and the mesodermic mesentery increases in thickness, in number of blood-vessels and nerves, an

extensive deposit of bundles of fibrous tissue takes place forming sheaths along the larger trunks of blood-vessels which appear to lie in the centre of the mesodermic mesentery, while the smaller vessels course laterally in large numbers immediately under the endothelial layers. A considerable layer of fine connective tissue lies on each side of the mesodermic mesentery, richly coursed by small blood-vessels. From the fourth foetal month onward the layered condition of the mesentery becomes more and more pronounced.

This true mesentery or middle plate of Remak was at first covered by a somewhat cubical mesothelium, and the formation of the true endothelium is probably due to a gradual process of transformation, whereby these cubical cells change into the flat endothelial. The endothelium is simply a lining membrane of the coelom, while the true mesentery is a mesodermic content projecting into the abdominal cavity, a bridge between the contained viscera and the dorsal wall holding in definite relation the vessels and nerves destined to supply the viscus. The endothelial layers are often transitory structures, liable to become lost by coalescence or displacement, while the middle mesentery is rarely ever lost except by thinning. Mesenteries arise from the dorsal wall, and those folds which arise otherwise, as the *ligamentum intestini caeci*, *ligamentum hepato-renale*, etc., are not mesenteries, but consist only of two endothelial layers, and do not possess a distinct system of blood- and lymph-vessels, or nerves and glands, imbedded in an intermediate fibrous layer of connective tissue.

Appendages of the Mesenteries.—(a) About the fifth foetal month, fat begins to be deposited in the meshes of the mesodermic mesentery, but not in its endothelial coverings. The earliest fat deposits are located in the omentum majus, and first appear as little isolated islands, distributed here and there in the connective tissue. The fat cells are recognised by their size, colour, round form, defined borders, fine granular formation, and large, round, clear nuclei; around them is a rich network of blood-vessels. The fat deposit in the omentum majus increases rapidly in the sixth and seventh foetal month, but less rapidly in the mesentery. In the eighth foetal month, and especially the ninth, the fat deposits become so well developed

that ornamental granular streaks of yellow fat may be observed in orderly arrangement shimmering through the endothelial layers of the mesentery along the blood-vessels, increasing in quantity from the viscera to the radix mesenterii, where large lobules of fat are accumulated. A few weeks subsequent to birth, fat lobules rapidly increase and form longer or smaller perceptible elevations in the endothelial layers of both omenta and mesentery. Fat deposits occur long before they are visible to the unaided eye, but the fat cells are rapidly mobilised to depots existing in the meshes of the middle mesenterial layer, whence arise the fat lobules. The fat deposit does not lie directly in contact with the endothelial layer, but beneath the *subserosa* above described.

In all the animals I have examined, fat was found in the omenta and mesenteries, arranged occasionally in ornamental fringes along the trunks and branches of vessels. This fat has a peculiar characteristic colour in different species of animals. I have seen the fat deposit in the human omentum over an inch thick. In the adult, the fat of the mesenteries is arranged in two layers, viz., one on each side of the mesodermic mesentery, between which lie the vessels and nerves so firmly bound in dense connective-tissue bundles that there is no room for the soft elastic fat globules in the centre of this layer. In an adult mesentery, there are therefore seven distinct layers, viz., (a) two external endothelial layers, (b) two subserous connective-tissue layers, lying immediately under and in contact with the endothelial layers, (c) two layers of connective tissue in which fat globules may arise and disappear, and (d) a central neuro-vascular connective-tissue layer, which represents the original conductive sheath of the vessels and nerves.

These various layers of the mesentery have signification in applied anatomy. The central mesodermic mesentery elongates in enteroptosis, the blood-vessels straighten out, the fibrous sheath of the vessels elongate or rupture, and the nerves are dragged and traumatised. Enteroptosis is perhaps a neurosis, in which innervation has allowed ill-nourishment and subsequent yielding of supports. It seems, indeed, as if the mesodermic mesentery elongates with every decade after thirty years of age.

The fat layers are storehouses for varying conditions of nourishment. They are more or less temporary, appearing and disappearing in certain ages and conditions. The two subserous layers lend to the endothelial layers their mobility, enabling portions of the peritoneum to glide freely about, and thus allowing the viscera to avoid trauma and friction. Some portions of peritoneum may be shifted 1 to 2 inches on their bases, returning to normal without losing their integrity, and this mobility endows the peritoneum with great utility for contracting and expanding and moving viscera. The membrana limitans, with its peculiar (diaphragmatic) perforations, is elsewhere described.

(b) A second appendage of the slowly developing mesentery is the lymph node (gland). The lymph nodes become visible in the mesentery in the fifth foetal month. To the eye and strong lens, they appear first as simply serially ordered elevations of the serosa, local modifications of the mesentery. The largest series of lymph nodes occur at the radix mesenterii, but they are also distributed along blood-vessel routes. They are enclosed in the mesodermic mesentery, which surrounds them with a fine fibrous trabecular capsule; and though they are developed in the centre of the mesodermic mesentery, yet they may be frequently noted projecting more to one side than the other.

(c) A third appendage of the digestive tract is the appendix epiploica (appendix Fallopii, or omentulum). The appendices epiploicæ exist along the entire ascending, transverse, and descending colon, and the greater portion of the *S. romanum*. The name 'omentula' was applied to these, doubtless, from their resemblance to the omentum majus. These appendices epiploicæ are sacs and folds of the peritoneal blades of the colon. They lie along the ligamentum intestinale or tænia coli, and may be so close together as to make a continuous serous fold, or they may be several inches apart. Their size varies from that of a pea to two or three inches long by two inches deep. The longer they are the more fat they contain, in fact the largest ones appear to depend on fat, and in each there is an artery and vein. They begin to appear about the fifth foetal month, and usually exist in two series, an outer and an inner,

of which the inner row is the larger. Along the transverse colon there is but one row of omentula. It is difficult to explain their origin or use; but they may originate around branches of the mesenteric arteries, and may be of the same use as the other omenta. I have seen similar folds of peritoneum on the dorsal peritoneum and on the mesentery. They aid to distinguish the large from the small bowel, and are possibly a remnant of structures existing in some ancient form of life. In fish it is common to see similar structures along the tractus intestinalis, in either a continuous or interrupted state. The omentula may be seen typically on each side of the appendices pyloricæ in some fishes.

That the mesentery consists of three layers was noted by Thomas Wharton (1656), Thomas Bartholinus (1686), Verheyen (1768), Albert von Haller (1774), and L. Ranvier (1875). However, the knowledge remained buried; but the modern revival of the view is chiefly due to the investigations of Professor Carl Toldt, the Vienna anatomist. Why has the mesentery been so long recognised in general as a duplicature of peritoneum? Anyone can easily satisfy himself that not only are there three layers in the mesentery, but that the layers are distinct from each other; yet for many centuries anatomists have considered the mesodermic mesentery as merely a subserous connective-tissue layer, binding the two endothelial (peritoneal) layers together, and conducting vessels and nerves to viscera. The mesodermic layer existed long before the two endothelial layers; in fact, it required some time before the original mesodermic cell mass became covered with flat endothelial plates (the non-genuine connective-tissue cell of His), whose development has been due to mechanical causes of pressure, motion, and friction, acting through ages of developing ancestors in shifting conditions of environment. The peritoneal cavity arose from the gradual coalescence of multiform interstitial lymph spaces of the mesoderm, which were by degrees lined with flat endothelial cells as they merged into the general coelomic lymph sac, to be utilised for motion, absorption, and transudation.

There are thus in a mesentery two distinctly functioning organs, viz., (1) a mesodermic mesentery connecting the viscera to the neuro-vascular centres, which is chiefly for mechanical or

anatomic purposes, and is constant; it endows the viscera with the requisite capacity for physiologic motion fitted to their mode of existence, it prevents strangulation or obstruction, and serves as a vessel-, gland-, and nerve-sheath. This mesodermic mesentery is projected forward at once from the dorsal wall, with its indifferent embryonal cells, in which are growing the mesenteric vessels and nerves. It develops *pari passu* with its accompanying viscus, and may exist without either endothelial covering, as in the adult human mesoduodenum, or without one mesenteric endothelial covering, as the mesocolon ascendens or mesocolon descendens. (2) A double layer of flat endothelial cells, one on each side of the mesentery, which facilitates motion and minimises friction, and also, as the wall of a lymph sac, it is endowed with absorbing and exudative powers. These endothelial layers of the mesentery are chiefly physiologic, and may be temporary.

In the case of the adult mesoduodenum, the mesodermic mesentery becomes a completely retro-peritoneal organ, with perfect preservation of its structure and contents.

The fate of the mesodermic mesentery in the mesogastrium differs in some degree from the same membrane in other localities. The original mesogastrium undergoes considerable change before arriving at adult life; part of it becomes the mesoduodenum, part becomes adherent to the dorsal wall almost precisely as the mesocolon descendens, and a third part becomes the gastro-colic omentum. As Professor Toldt describes, the portion of the mesogastrium which is most distant from origin or insertion has no real mesodermic mesentery; and its blood-vessels, lymph structures, and nerves are very few. In fact, the middle portion of both omentum majus and minus consists of a simple connective trabecular tissue, covered on each side by an endothelial layer. The arteriæ gastro-epiploicæ nourish the insertion of the mesogastrium where there is a distinct mesodermic mesentery, while the branches of the celiac axis nourish the origin of the mesogastrium, where is also found a distinct mesodermic mesentery; but in the middle the mesenterial endothelial layers of both sides remain, while the essential mesodermic mesentery is almost faded out; it has been stretched beyond its integrity by the still unexplained enormous develop-

ment, and is degenerating. However, it may be observed that even in the points most distant from the origin and insertion of the omentum, considerable deposit of connective tissue ensheath large blood-vessels, although the small ones have disappeared. The slight remnant of fibrous connective-tissue meshwork found in the middle portions of the omentum is the vestige of the mesodermic mesentery yet following the inevitable course of useless organs.

In the middle portions of the omentum majus and minus are found apertures which Ranvier attributed to the penetration of leucocytes. It appears improbable that these could make penetrations which would ultimately end in such large apertures. These apertures of the omentum are more likely due to the degeneration of the mesodermic mesentery and of both endothelial layers, produced by a process of stretching or rarefaction of tissue.

The blood-vessels are among the most significant factors in the development of the mesenteries. For the mesentery of the digestive tract there are three arteries, which nourish three distinct regions, with their corresponding portions of bowel. The first region is the mesogastrium (which includes the mesoduodenum), and should be named the 'mesenterium gastroduodenale.' It is nourished by the coeliac axis, with its three branches, gastric, hepatic, and splenic arteries. The digestive tract included is the stomach and duodenum. This is the mesentery of the coeliac axis and its branches. His and others claim that the *duodenum transversum* and *ascendens inferior* belong, with their corresponding mesenteries, to the mesenterium and navel loop. The second region of the mesentery is that supplied by the superior mesenteric artery, which extends from the flexura duodeno-jejunalis to the flexura coli lienalis. The digestive tract included in this blood supply is the jejunum, ileum, cæcum, ascending and transverse colon. It includes the business portion of the digestive tract, and forms the navel loop. This region includes the *mesenterium*, *mesocolon ascendens et transversum*. This is the mesentery of the superior mesenteric artery. The third artery of the digestive tract influencing the development of the mesentery is the inferior mesenteric. It nourishes the left mesocolon and mesosigmoid.

and includes the descending colon, sigmoid, and rectum, the faecal reservoirs. This is the mesentery of the inferior mesenteric artery. These three arteries supply three distinct regions of the original mesentery, and by tracing those arteries in the adult, the secondary changes of position and growth in the mesentery may be observed step by step. The mesentery is modified very much by the mechanical influence of its own blood-vessels. The differentiation of the digestive tract into unequal regions begins with the development of the stomach, which may be observed as a spindle-shaped organ at the fourth week. Early in the development of the mesenteries, the three arteries (coeliac, superior and inferior mesenteric) were included in a common sagittally directed mesentery, extending along the dorsal wall from mouth to rectum; but as the alimentary tract grows much more rapidly in length than the body, the tube, in order to make room for itself, begins to form loops or assume a tortuous course. From ontogenetic and phylogenetic researches it would appear that each body segment originally had its intestinal artery, just as it has its intestinal nerve. It has long been known that certain amphibians and reptiles possess a series of small arteries arising from the aorta to supply the digestive tract. This perhaps represents the original conditions, and would remain so while the length of the body corresponded to that of the digestive tract and its mesentery. However, with the advance in scale of life, the length of the digestive tube and mesentery rapidly exceeds the body length, and reduction and concentration of the number of intestinal arterial trunks become a necessity. The intestinal arteries gradually fused into permanent trunks. Hyrtl demonstrated that the reduction of the intestinal arteries occurred in the region of the coeliac axis in *Cryptobranchus Japonicus*, and that similar reductions of intestinal arteries occur in *Menopoma*, *Salamander*, and *Triton*. Klaatsch has also shown that fusion of intestinal arteries occurred in amphibians, reptiles, and monotremes. The fusion and reduction has been chiefly with the coeliac and superior mesenteric arteries, for the inferior mesenteric artery appears as a very constant representative. I am inclined to suggest that the hæmorrhoidals from the internal iliacs are representatives of ancient intestinal arteries. The reason for the

permanent trunk of the superior mesenteric artery doubtless lies in its relation to the omphalo-mesenteric vessels, the umbilical vessels, the navel loop, with its extrusion and retraction into the abdominal cavity.

With the growth of the digestive tract, the liver, spleen, pancreas, and genito-urinary organs, the mesenteries assumed three distinct regions, and are supplied by the three arteries. The chief changes in the location of the original sagittal mesentery are due to growth, pressure, coalescence or displacement of the endothelial layers. In the mesogastrium the thinned-out mesoblast originally arose from the middle of the dorsal wall immediately under the aorta, but in the second month it becomes not only displaced to the left, but enormously elongated. The chief factor in displacing and elongating the mesogastrium is the large foetal liver, which forces the stomach into a horizontal position, and at the same time rotates it from left to right (inducing the left vagus to appear on the front wall of the stomach, while the right vagus lies on the posterior wall). The double rotation of the stomach occurred very early, for it displaced the gastric artery from the origin of the mesogastrium to the opposite side of the stomach in the smaller curvature, while the greater curvature in adults is supplied by later developed arteries, the gastro-epiploica dextra and sinistra (from the hepatic and splenic). The hepatic artery, originally intended to supply the lower end of the stomach, has been monopolised by the liver. The splenic artery, originally supplying the middle of the stomach, has been directed to the growing spleen. The forcing of the mesogastrium to the left by the liver forms a depression which gradually deepens and enlarges to an immense bag (*cavum omentalis minoris*), and during the process a large portion of the left wall of the mesodermic mesentery becomes adherent to the dorsal abdominal wall. The mesogastrium contains the spleen and pancreas, the tail and body of which become retro-peritoneal. In the second embryonal month the mesogastrium assumes relations with the transverse and ascending colon, which become gradually enclosed in its blades from right to left.

The right portion of the omentum majus (*omentum colicum Halleri*) may extend along the ascending colon to the entering

ileum. The portion of the omentum extending from the greater stomach curvature to the transverse colon is the *omentum gastro-colicum*, and the portion extending below the transverse colon is the *omentum colicum*.

The mesogastrium is characterised by its rapid extension to a vast surface area, but the mesodermic mesentery decreases until its fibres atrophy and forms a lattice-work. Some of the smaller apertures may still be closed by the peritoneal mesentery, but the large ones become distinct open holes. Thus arises the peculiar reticular structure of the omentum majus at a distance from large blood-vessels. Along large blood-vessels it retains its mesodermic mesentery.

The intense proliferating growth of the mesogastrium asserts itself not only in surface area but also in villiform, wedge-form, or glove-finger-form processes, which are found frequently along the principal blood-vessel trunks. The origin and signification of these processes is unknown. The formation of the bursa of the mesogastrium (cavity of the great omentum) occurs as a depression in the right wall of the mesogastrium. The opening into the cavity of the great omentum corresponds exactly to the original root line of the mesogaster.

The foramen leading into the cavity of the great omentum I have designated as Huschke's foramen, in honour of Professor Huschke of Jena (died 1858), who gave one of the first exact descriptions of it. This is a vascular ring, bounded by the hepatic, gastric, and pyloric arteries. The peritoneal borders of Huschke's vascular ring are the *plica gastro-pancreatica* (*septum bursarum omentale*), a fold extending from the pancreas to the cardia, projected upward by the gastric artery, and the *plica arteriæ hepaticæ*, a fold thrown up by the hepatic artery, and extending from the celiac axis to the point of branching of the pyloric artery. Huschke's foramen usually is large enough in the adult to admit the hand. To observe the foramen, break through the *pars flaccida* of the omentum minus, whence the circular vascular ring appears from the right side; or one can tear through the gastro-colic omentum, and the foramen will appear from the left side.

Huschke's foramen opens on the right side into a vestibule (*bursa omentalis minoris*) containing Spiegel's lobe of the liver.

It opens on the left side into the lesser cavity of the omentum (*bursa omentalis majoris*). The space on the right side into which Huschke's foramen opens is bounded anteriorly by the omentum minus, posteriorly by the parietal peritoneum, and proximally closed in by the liver and diaphragm. This space is in the primitive anteroom or vestibule of the lesser omental cavity. Huschke's foramen is entirely different in origin, locality, and size from Winslow's foramen.

Winslow's foramen is bounded anteriorly by the *ligamentum hepato-duodenale* (containing the hepatic artery, duct, and portal vein), and posteriorly by the vena cava ascendens. It is almost a vascular foramen. In adults it admits two fingers. It might be called, as Klaatsch suggests, the *foramen hepato-entericum*. Winslow's foramen leads along the dorsal peritoneum into the vestibule or anteroom which opens into the lesser omental cavity through Huschke's foramen.

The terms *bursa omentalis majoris et minoris* should be dropped or changed unless they refer to different subjects than formerly. The *bursa omentalis majoris* should be termed *bursa gastro-mesentericum*. The *bursa omentalis minoris* should be called an anteroom or vestibule to the above. Perhaps it would be better to term it *bursa hepato-enterica*, as suggested by Klaatsch.

Klaatsch suggests that Winslow's foramen, or *foramen epiploicum*, is a perforation of the ventral mesentery, *i.e.*, a secondary formation from modification of the mesodermic and peritoneal mesenteries.

By the active growth of the stomach the arteries became rapidly developed. When the mesogastrium was forced to the left by the liver it carried with it the splenic artery; when the liver dragged the mesoduodenum to the right it carried with it the hepatic artery; hence the difference in direction of these two arteries. However, when the rapid development and twisting of the stomach occurred, the gastric artery could not follow or keep pace, hence lost its original place on the greater stomach curvature, and was forced into the lesser curve of the stomach, and lies in the *ligamentum gastro-pancreaticum*. The inferior portion of the mesentery, of the celiac axis, is the mesoduodenum, which became dragged to the right by the

diminishing liver, exactly in the opposite direction to the mesogastrium. It is supplied by a branch of the hepatic artery which originally supplied the lower end of the stomach. Originally, the mesoduodenum was free, inserted in the median dorsal line, covered on both sides by a layer of endothelial cells; gradually about the end of the third foetal month the mesoduodenum lost these, its right side became fixed to the dorsal wall, and the endothelial layer of its left face is appropriated by the cæcum on its travels to the left iliac fossa. The spiral formation of the duodenum is perhaps due to the head of the pancreas and the fixation of the *flexura duodeno-jejunalis* on the dorsal wall. Perhaps it is enhanced by the right kidney and adrenal, and the expansion of the right dorsal wall. In animals (dog and cat) it remains free, and covered on both sides by endothelium. The mesoduodenum, *i.e.*, the mesodermic mesentery, exists in man to convey vessels and nerves to the duodenum; its absence is only apparent because it is deprived of its endothelial layers, and it has become adherent to the dorsal wall. The mesoduodenum contains the head of the pancreas, while the body and tail is in the left portion of the mesogastrium. The chief artery which nourishes the mesoduodenum is the *pancreatico-duodenalis superior*.

The second artery of the mesentery of the digestive tract is the superior mesenteric artery, which nourishes the bowel with its corresponding mesentery from the *flexura duodeno-jejunalis* to the *flexura coli-lienalis*.

In mammals it is easily observed that the large mesentery area of the superior mesenteric artery has but a very short proximal root line. Its peculiar branching (arcades of the *vasa intestini tenuis*) is due to the growth in the course of the narrow mesentery of the navel loop. All permanent positions and connections of this loop are due to secondary changes. During the fourth and fifth foetal month the colon and mesocolon ascendens become broadly fixed to the left face of the mesoduodenum, the anterior surface of the right kidney, and the dorsal wall. As a result of these changes, the mesentery of the superior mesenteric artery becomes divided into three portions, *viz.*, (a) the free mesenterium of the small intestine, (b) the fixed mesocolon ascendens, and (c) the free mesocolon transversum.

The insertion of the transverse mesocolon is simply the growing border line of the mesocolon ascendens and descendens, while the insertion line of the mesenterium is the medial growing border line of the mesocolon ascendens (Toldt). The changes from the normal adult position in the navel loop are chiefly found in the ascending colon and mesocolon. The ascending colon normally has no mesentery, but in anomalous conditions it may have three kinds of mesenteries, viz., (a) a mesentery below the right kidney, (b) one on the right kidney and (c) one above the right kidney. As the navel loop rotation or the journey of the cæcum to the right iliac fossa is merely a matter of growth change, its source of blood supply does not change, but it is nourished from beginning to end by the superior mesenteric artery. Hence, by following out the direction of the branches of the superior mesenteric artery, we can determine the position and fate of any portion of the mesentery of the navel loop, and the border line between it and all other segments of the mesentery of the digestive tract may be located. The region of the digestive tract, supplied by the celiac axis and that supplied by the superior mesenteric artery, is connected by the pancreatico-duodenalis inferior, while the region of the digestive tract, supplied by the inferior mesenteric artery, is connected to the navel loop by an anastomosis of the colica media and sinistra at the *flexura coli lienalis*. Ages of evolutionary processes and increased function have established these three arteries, all others having dropped out of existence. The occasional occurrence of accessory arteries only prove the views to be correct. Accessory arteries to the liver may sometimes arise from the superior mesenteric. The mesentery of the superior mesenteric artery may be absent, with the exception of sufficient length to carry the vessel from the aorta to the bowel, as reported by Lawson Tait, Meckel, Cabrol, Bellot, and Dionis. In such cases the bowel extends in length only from diaphragm to rectum. The region of the digestive tract supplied by the superior mesenteric artery may remain with a common mesentery. The navel loop may not rotate; and if it does, it may still remain with a larger and shorter *mesenterium commune*, which might endanger life by establishing tendencies to volvulus.

If the mesentery of the superior mesenteric artery does not

assume secondary attachments, as it has a short radix mesenterii, it might easily rotate pathologically. The chief anomalies of the navel loop arise from the partial or complete interruption of the journey of the cæcum into the right iliac fossa; in other words, they are due to the interruption of the fixations of the ascending colon. A complete mesenterium commune would require a free mesogaster and mesoduodenum for the arteries of the coeliac axis, and a free mesentery for both the arteries mesenterica superior and inferior. Such a case I have not met once in over 500 autopsies. Atrophy of the mesodermic mesentery may be noticed at the borders of these different mesenteries, as at the junction of the mesenterium with the mesocolon ascendens, where the branches of the ileo-colic artery leave thin places or even apertures between them.

In the examination of bodies it may be noticed that four groups of anomalies may arise in regard to the mesentery of the mesenteric superior artery, viz., (a) A group in which the colon forms a distinct *ligamentum hepato-colicum*. In this group the large bowel may be fastened by the ligament to the liver or to the whole gall bladder. The *ligamentum hepato-colicum* (an extension of the *ligamentum hepato-duodenale*) limits the movements of the colon ascendens and transversus, and it saves many patients by circumscribing infectious processes from the gall bladder, as it forms a barrier to check disseminating pathogenic microbes from a ruptured gall bladder. (b) A second group in which there is no *ligamentum hepato-colicum*. This allows wide movements to the colon ascendens and transversum. (c) Transposition of the viscera may occur. (d) The upper end of the jejunum may become fixed on the inferior surface of the transverse mesocolon for several inches, which occurs quite frequently.

The mesentery of inferior mesenteric, the simplest of the three arteries, extends from the splenic flexure to the rectum, and includes the descending colon and sigmoid. The mesocolon descendens in the usual anatomic sense should be absent, as the endothelial layers on each side of the mesodermic mesentery do not come in contact between the descending colon and the dorsal wall. The mesentery of the descending colon was originally inserted in the median dorsal wall. By degrees, through

pressure of the packet of small intestines and the liver, and the growth of the left kidney, the *mesocolon descendens* becomes forced to the left, its left endothelial layer becomes appropriated by the growing kidney and abdominal wall, and the left face of its mesodermic mesentery becomes adherent to the dorsal wall as far as the left border of the left kidney. All the inferior mesenteric blood-vessels of the mesodermic mesentery are carried to the left with it. The endothelial (peritoneal) layer of the right face of the descending colon remains permanently in position. In most animals the descending mesocolon remains free on both sides, with its artery in the median line; and in man, the nearer the descending colon is to the median dorsal line, the more apt it is to possess a mesocolon; but this is an uncommon variety. It is a peculiar feature in regard to the development of this mesentery that the mesentery of the descending colon is adherent to the dorsal wall, while the mesentery of the sigmoid flexure is free, the adhesion of the mesodermic mesentery becoming interrupted at the lower pole of the left kidney. A remnant of this obscure process is the intersigmoid fossa. This artery anastomoses with vessels of the dorsal wall—the internal iliac. By analysing the mesentery into its original constituents, the mesodermic mesentery and the two endothelial layers, we can understand its origin and permanent position, and apply its anatomy in surgical procedures.

The endothelial layers which do not include a mesodermic mesentery are true peritoneal folds, which project with free borders into the abdominal cavity. These *ligamenta peritonei* are either raised from the abdominal wall itself, or stretched from the dorsal wall to a viscus, or from one viscus to another, or they may arise from a mesentery and span between it and a viscus. Such peritoneal folds are local formations, and in origin and nature dependent on abdominal space-relations. On this account they show much variation as to form, position, and extent. In the normal dead body, one can artificially, through the mobility of the peritoneal layer on its subserous base, change the existence, form, origin, and extent of these *ligamenta peritonei* by dragging on adjacent viscera. Hence many *ligamenta peritonei* are temporary, arising and disappearing by changes of

peritoneal relations. They are entirely different in nature from the mesodermic mesentery. These may be divided into two kinds, viz., (a) vascular peritoneal folds, and (b) free non-vascular peritoneal folds. The vascular peritoneal fold contains a blood-vessel, hollow tube or muscle, in its free border, but the vessel may not finally remain in the free border of the fold, but may lie at some distance from the edge. As typical examples of vascular peritoneal folds may be mentioned the *plicæ arteriæ hypogastricæ*, projected by the obliterated hypogastric arteries, *plica urachi*, *plica gastro-pancreatica*, *plica duodeno-jejunalis*, *plica ileo-cæcalis*, *plica hepatico-umbilicalis*, *ligamentum infundibulo-pelvicum*, *plica arteriæ hepaticæ*. The free non-vascular peritoneal folds have no essential contents, but are simply two endothelial layers as the *plica intestini cæci*, occasionally the *plica duodeno-jejunalis* when without a blood-vessel, *plica ileo-cæcalis*, *ligamentum coronarium hepatis*, *ligamenta hepatis triangularia dextrum et sinistrum*, *ligamentum diaphragmaticum*, *ligamentum mesosigmoideo-mesenterium*, and *plicæ pubovesicales* or Douglas's folds. If the folds become permanent, the two blades generally become adherent to each other, not allowing shifting, as does the normal peritoneum on its loose subserous base.

The word 'mesentery' has in common use become generalised. Properly, the mesentery indicates the mesodermic layer, covered on each side by a layer of endothelial cells, which anatomically and physiologically connected the digestive tract to the dorsal wall. Recent writers generalise the term as cardiac mesentery, the mesentery of the inferior vena cava, uterus, ovary, testicle, kidney, Wolffian body, liver, bladder,—in short, any peritoneal organ may possess a mesentery. This generalisation does not essentially advance knowledge, nor ought it to materially confuse by new names, for the original mesentery is easily differentiated from others genetically, morphologically, and functionally. No advance in the knowledge of the mesentery can be expected while the old view is retained, which considers a mesentery as a duplicature of the peritoneum. In spite of the epoch-making labours of Meckel (1817), Müller (1830), Huschke (1844), Treitz (1857), Langer (1860), Gruber (1861), Henle (1870), Waldeyer (1874), Toldt (1879), Tarnetzky (1881), Zoener (1881), Treves (1885), Klaatsch (1892), and others, the correct

view of the mesentery and its development does not appear in modern English text-books on anatomy. Unfortunately, the teaching that a mesentery is a duplicature of peritoneum is as old as anatomy itself. But at no period of life does the mesentery consist only of a duplicature of peritoneum; for, as we have seen, even in the first embryonal month the two constituents of the mesentery, mesodermic and peritoneal, are differentiated. The endothelial layers always remain the same thin lymphatic membrane, while the middle mesodermic layer gradually becomes differentiated into a central firm layer, which conducts nerves and vessels, with a loose layer on each side, which allows the peritoneal layers to shift and glide about. The root line or proximal end of the mesodermic mesentery does not suspend from the peritoneal layers, but directly from the retroperitoneal connective tissue, especially that which surrounds the aorta; and the distal end of the mesodermic mesentery passes with its vessels and nerves into the parenchyma of the organ. The mesodermic mesentery remains intact with its contents, even if the two peritoneal layers be stripped off from its sides.

The secondary growth-changes of the dorsal mesentery of the digestive tract consist in the increase of surface area, changes in its position, and changes in its connection. The gradual increase of mesenteric surface stands in direct relation to the length of the bowel, and also to the distance between the proximal and distal border of the mesentery. The bowel which has the freest mesentery has the most intense growth-activity. A bowel segment such as the duodenum loses its active growth when it becomes fixed, and in consequence all portions of bowels with a fixed mesenterial segment remain relatively shorter than the portions of bowels with free mesenterial segments.

The change of position which the growing bowel and mesentery experience has been known from the days of Meckel and Müller. In modern times its details have been shown by Toldt, Klaatsch, Endres, and others. The mesodermic mesentery remains an independent structure after its fixation to the dorsal wall or to the left face of the mesoduodenum, and grows as before, but with much less rapidity. The secondary

and includes the descending colon, sigmoid, and rectum, the faecal reservoirs. This is the mesentery of the inferior mesenteric artery. These three arteries supply three distinct regions of the original mesentery, and by tracing those arteries in the adult, the secondary changes of position and growth in the mesentery may be observed step by step. The mesentery is modified very much by the mechanical influence of its own blood-vessels. The differentiation of the digestive tract into unequal regions begins with the development of the stomach, which may be observed as a spindle-shaped organ at the fourth week. Early in the development of the mesenteries, the three arteries (coeliac, superior and inferior mesenteric) were included in a common sagittally directed mesentery, extending along the dorsal wall from mouth to rectum; but as the alimentary tract grows much more rapidly in length than the body, the tube, in order to make room for itself, begins to form loops or assume a tortuous course. From ontogenetic and phylogenetic researches it would appear that each body segment originally had its intestinal artery, just as it has its intestinal nerve. It has long been known that certain amphibians and reptiles possess a series of small arteries arising from the aorta to supply the digestive tract. This perhaps represents the original conditions, and would remain so while the length of the body corresponded to that of the digestive tract and its mesentery. However, with the advance in scale of life, the length of the digestive tube and mesentery rapidly exceeds the body length, and reduction and concentration of the number of intestinal arterial trunks become a necessity. The intestinal arteries gradually fused into permanent trunks. Hyrtl demonstrated that the reduction of the intestinal arteries occurred in the region of the coeliac axis in *Cryptobranchus Japonicus*, and that similar reductions of intestinal arteries occur in *Menopoma*, Salamander, and Triton. Klaatsch has also shown that fusion of intestinal arteries occurred in amphibians, reptiles, and monotremes. The fusion and reduction has been chiefly with the coeliac and superior mesenteric arteries, for the inferior mesenteric artery appears as a very constant representative. I am inclined to suggest that the hæmorrhoidals from the internal iliacs are representatives of ancient intestinal arteries. The reason for the

mesentery of the vena cava inferior. In a similar way, the descending colon becomes fixed by the colon becoming included in the ligamentum recto-lienale and by this means acquiring a fixation on the dorsal wall. To the views of Dr Klaatsch I do not, so far, see my way clearly. If our views on the mesenteries of the digestive tract must rest on a correct base, they must include embryonic development, definite reference to the mechanical influence of blood-vessels, original and secondary mesenteric root lines, and secondary changes in both mesodermic and peritoneal mesenteries.

The increase of the mesenterial surface offers some points of interest, especially that of the mesogastrium. In a certain sense, the length of the bowel is in accordance with the size of the mesenteric surface, but there are four kinds of these relations: (a) The short stomach, with its enormous mesogastrium, developed so far as known beyond all requirements, at least out of proportion to the length of the stomach. (b) The small intestine, with its mesenterium of vast surface area, of many square feet. But the small bowel is greater in proportion to its mesentery than the stomach and sigmoid. (c) The transverse colon, with a liberal mesenteric supply. (d) The area of the vertical colon and the duodenum, with their mesodermic mesenteries fixed against the right or left dorsal wall. Such fixed segments of bowel have the least area of mesentery. The peritoneal mesentery belongs to all of the above four classes except to the mesoduodenum. The carnivora have relatively a short colon, with a considerable mesenteric area. The ruminants, as well as the horse and pig, have a long colon, with a relatively small mesenteric area. Dr Carl Toldt observes that the short colons of apes or half apes possess a large mesenteric area. The economy of the mesentery is apparent in the colon, as in the horse, where a short mesentery will lie between two long parallel portions of colon. A similar economy, but less apparent, may be observed in the mesentery of the small intestines of embryonic man or the dog. In general, the mesenteric area of each bowel segment stands in relation to the length, position, and form of the bowel.

As regards the cause of the shifting and final disposition of the digestive tract and its mesentery, we may begin with the

because the blades of the peritoneum do not definitely come in contact with each other between the colon and dorsal wall, but it always has a mesodermic mesentery, containing its vascular and nervous supplies. The left colon has suffered the same change as the duodenum, except that the colon has lost but one (the left) endothelial layer, which was appropriated by the rapidly growing kidney and lateral abdominal wall. The same may be said of the right colon, except that the acquired developmental processes are more extensive and complicated than those affecting the left colon. By the separation of the layers of a mesentery, the organ becomes limited in motion, as in the case of the right and left colon and duodenum. In the omenta a somewhat different process occurs. The two endothelial layers persist, while the mesodermic mesentery almost, if not entirely, disappears, especially in the part of it which is equidistant from origin and insertion, or the point of greatest tension.

From the first appearance of the embryonal tract of cells on the middle dorsal wall to the completed mesenteries of the foetus, the complicated processes through which they pass consist in changes of relation of the three layers. These changes arise by elongation, by unequal growth and pressure of viscera, by appropriation, displacement, or coalescence of the peritoneal blades, and by the mesodermic mesentery becoming retro-peritoneal.

Such changes have practical applications in surgery. The cæcum, as it passes over the left face of the mesoduodenum, elevates and appropriates the left endothelial blade to cover itself; and the right face of the mesoduodenum, deprived of its peritoneal layer, is bound fast to the dorsal wall, fixing the duodenum in the shape of a spiral ring, which of course makes it deficient in peristalsis, and also the curve in the duodenum makes it much more difficult to force the food onward. The left face of the left mesocolon loses its left endothelial layer, and the mesodermic mesentery becomes firmly attached to the dorsal wall, from the median line to the external border of the left kidney. Thus the left colon is materially altered by the changes, both for function and surgery. The fixation of the left colon lessens peristaltic force, and in surgical procedures it suggests that we should never, if avoidable, tear through the

this purpose is difficult to attain, and the field is uncultivated as to literature. I cannot agree with Dr Klaatsch that the problem of the *situs peritonei* offers no further difficulties, but it matters little how much comparison of early vertebrate mesenteries are made until we understand the details of the present forms. The position assumed by the jejuno-ileum, with its mesenterium in the left iliac region, is no doubt due to the large foetal liver forcing the packet of small intestines before it in that direction. This condition is observable in a three months embryo, and it is a matter of abdominal space relation. Doubtless the shape of the dorsal wall mechanically aids in influencing the *situs peritonei* as well as the resisting parenchymatous organs, as the spleen, kidney, pancreas, and especially the liver. In other words, the typical growth relations of certain bowel segments, in connection with that of the growth of the dorsal wall and adjacent organs, make space relations an essential cause of the position of both bowel and mesentery, and of size and rate, and explain to a certain extent the variation of the *situs peritonei*. The relative stiffness of the dorsal wall may account for the dorsal fixation of the mesentery, for it requires an intimate contact and non-mobility of peritoneal blades to coalesce. Endres has thrown light on the subject of mechanical influences of blood-vessels on the *situs peritonei*.

The mesentery may not only become adherent to the dorsal wall, but one mesentery may adhere to another, as that of the colon ascendens which lies on the left face of the mesoduodenum. The proof that the peritoneal layers coalesce or grow together instead of becoming displaced rests on (a) the ease of separating them shortly after the occurrence; (b) the cicatricial tissue found in the tract of coalescence; (c) the gradual spreading of the connection between the effaced endothelial surfaces; (d) the permanence of the mesodermic mesentery in the fixed mesentery; (e) on sections of embryos in different ages where the two opposed, free, endothelial layers are found entirely circumscribed by the advancing and surrounding coalescence; (f) the local interruption of coalescence of the folds, as in the recessus para-colici and intersigmoid fossa; (g) the different grades of coalescence in individuals. Microscopic investigations on the coalescence of the peritoneal layers are not always

extensive deposit of bundles of fibrous tissue takes place forming sheaths along the larger trunks of blood-vessels which appear to lie in the centre of the mesodermic mesentery, while the smaller vessels course laterally in large numbers immediately under the endothelial layers. A considerable layer of fine connective tissue lies on each side of the mesodermic mesentery, richly coursed by small blood-vessels. From the fourth foetal month onward the layered condition of the mesentery becomes more and more pronounced.

This true mesentery or middle plate of Remak was at first covered by a somewhat cubical mesothelium, and the formation of the true endothelium is probably due to a gradual process of transformation, whereby these cubical cells change into the flat endothelial. The endothelium is simply a lining membrane of the coelom, while the true mesentery is a mesodermic content projecting into the abdominal cavity, a bridge between the contained viscera and the dorsal wall holding in definite relation the vessels and nerves destined to supply the viscus. The endothelial layers are often transitory structures, liable to become lost by coalescence or displacement, while the middle mesentery is rarely ever lost except by thinning. Mesenteries arise from the dorsal wall, and those folds which arise otherwise, as the *ligamentum intestini caeci*, *ligamentum hepato-renal*e, etc., are not mesenteries, but consist only of two endothelial layers, and do not possess a distinct system of blood- and lymph-vessels, or nerves and glands, imbedded in an intermediate fibrous layer of connective tissue.

Appendages of the Mesenteries.—(a) About the fifth foetal month, fat begins to be deposited in the meshes of the mesodermic mesentery, but not in its endothelial coverings. The earliest fat deposits are located in the omentum majus, and first appear as little isolated islands, distributed here and there in the connective tissue. The fat cells are recognised by their size, colour, round form, defined borders, fine granular formation, and large, round, clear nuclei; around them is a rich network of blood-vessels. The fat deposit in the omentum majus increases rapidly in the sixth and seventh foetal month, but less rapidly in the mesentery. In the eighth foetal month, and especially the ninth, the fat deposits become so well developed

that after many examinations of variously aged embryos, such proofs appear limited. The method of demonstrating this fusion consists in attempting to break up the recently formed fusion or coalescence, as, for example, between the abdominal wall and the mesocolon descendens, by freeing the mesocolon descendens from the dorsal wall to the median line, where it originally arose, covered on both sides with the endothelial plates. Two peritoneal surfaces can coalesce or fuse only when the endothelial cells desquamate and produce a condition where the connective-tissue cells form a union. Or endothelial cells must so change that connective-tissue cells of similar nature unite or fuse. It is doubtful whether Broesike's 'partial formative imitation' has aided us in understanding coalescence of peritoneal blades, especially since we do not know in what formative imitation consists. It only asserts that a certain tendency exists between opposing peritoneal blades to coalesce, not only in intra-uterine but in extra-uterine life. Possibly a kind of intercellular substance may arise from the contact of the two peritoneal layers, inducing them to coalesce. The theory of coalescence of peritoneal folds is difficult to prove, as it presumes certain facts without reasonable explanation, and in so far is dogmatic. The theory presents insufficient explanation as to why in certain localities peritoneal folds coalesce, and not others which are equally in contact, possess like histologic characters, and are apparently subject to similar friction and pressure. The coalescence of peritoneal folds occurs chiefly with those attached to the dorsal wall. As illustrations of the coalescence theory, it is claimed by Toldt that the intersigmoid fossa and the recessus para-colici are simply interruptions of the coalescing process. It might, with equal force, be asserted that the points of interruptions in the paths of coalescence were due to a local non-displacement of the peritoneal layers. The closure of the processus vaginalis is important evidence for the coalescence theory, but this fails to explain the relations of the transverse colon and of the mesogastrium. Coalescence may be aided by muscular trauma producing adhesive inflammation of the delicate peritoneal folds, as it chiefly occurs in the region of the dorsal wall. The muscles involved in causing trauma are the diaphragm and its pillars (crura), the psoæ, and those of the

The fat layers are storehouses for varying conditions of nourishment. They are more or less temporary, appearing and disappearing in certain ages and conditions. The two subserous layers lend to the endothelial layers their mobility, enabling portions of the peritoneum to glide freely about, and thus allowing the viscera to avoid trauma and friction. Some portions of peritoneum may be shifted 1 to 2 inches on their bases, returning to normal without losing their integrity, and this mobility endows the peritoneum with great utility for contracting and expanding and moving viscera. The membrana limitans, with its peculiar (diaphragmatic) perforations, is elsewhere described.

(b) A second appendage of the slowly developing mesentery is the lymph node (gland). The lymph nodes become visible in the mesentery in the fifth foetal month. To the eye and strong lens, they appear first as simply serially ordered elevations of the serosa, local modifications of the mesentery. The largest series of lymph nodes occur at the radix mesenterii, but they are also distributed along blood-vessel routes. They are enclosed in the mesodermic mesentery, which surrounds them with a fine fibrous trabecular capsule; and though they are developed in the centre of the mesodermic mesentery, yet they may be frequently noted projecting more to one side than the other.

(c) A third appendage of the digestive tract is the appendix epiploica (appendix Fallopii, or omentulum). The appendices epiploicae exist along the entire ascending, transverse, and descending colon, and the greater portion of the *S. romanum*. The name 'omentula' was applied to these, doubtless, from their resemblance to the omentum majus. These appendices epiploicae are sacs and folds of the peritoneal blades of the colon. They lie along the ligamentum intestinale or tænia coli, and may be so close together as to make a continuous serous fold, or they may be several inches apart. Their size varies from that of a pea to two or three inches long by two inches deep. The longer they are the more fat they contain, in fact the largest ones appear to depend on fat, and in each there is an artery and vein. They begin to appear about the fifth foetal month, and usually exist in two series, an outer and an inner,

the same amount of peritoneal coalescence. Hitherto, this theory has been supported by relatively few great authorities, among which may be noted Langer, Meckel, Toldt, and Klebs.

The second or displacement theory postulates a process of shifting or displacement of the endothelial layers in such a manner that what was once free peritoneal surface remains free. The majority of the great authorities of the past favoured it, as Treitz, Luschka, Meckel, Müller, Zoerner, Hyrtl, Waldeyer, and others. This theory accounts for the secondary condition or position of viscera, by supposing that one or both of the endothelial layers became displaced or shifted from the surface of the mesodermic mesentery, which in general subsequently becomes retro-peritoneal,—that is, behind the endothelial layers. The lateral endothelial layers of the mesentery become appropriated through dragging by the abdominal wall to line its rapidly growing surface, but the whole process must be considered as a matter of slow growth. Modern writers note that unequal growth plays a fundamental rôle in adjusting peritoneal folds; for example, Bischoff noted the theory of peritoneal folds in 1842, in his *Entwicklungsgeschichte*.

Some free non-vascular and non-muscular peritoneal folds arise from unequal dragging of adjacent organs, as the *plica intestini caeci* (Huschke's fold), *plica mesenterico-colicum* (Gruber's fold), and *plica duodeno-jejunalis* (Huschke's fold) when non-vascular. The displacement theory does not contemplate any sudden gross dragging or especial activity in any one organ, but that in certain localities gradual processes of growth of viscera, step by step, change the endothelial (peritoneal) layers in position and relation. That such difference can be brought about by growth-changes is plain, when one recalls the changes in the descent of the testicle. The displacement theory demonstrates that out of the simplest relations of a vertical straight mesentery by growth-processes, the most complicated peritoneal duplicatures may arise slowly and almost imperceptibly. Again, a view may be presented, originated by Zoerner, which holds that the lateral and medial endothelial layers of the ascending and descending mesocolon do not grow equally, consequently the external lateral layers appear to shorten, while the internal ones lengthen, ending in the right and left colons

being situated against the extreme lateral abdominal walls with no mesocolon as regards endothelial blades. The mesodermic mesentery grows apace with the internal lateral peritoneal blades; but this is a special modification of the idea of appropriation by the abdominal walls of the lateral endothelial blade of the vertical colons. The mesenteries of the digestive tract are usually complete at two years after birth, and they do not suffer very marked changes until about thirty years of age, when in general they elongate perceptibly every decade.

The signification of the mesenteries is involved in the anatomic and physiologic relations of the viscera and peritoneal cavity. The peritoneal cavity is a colossal joint whose walls are rich in lymphatics, a vast bursa submucosa. The mesenteries are but invaginated parts of the joint surface. All mobile organs which are subject to considerable contraction and expansion requires a mesentery or a neuro-vascular visceral pedicle. Every organ must possess anatomic limitations, so that it can execute its physiologic functions.

The mesenteries prevent entanglements, yet ensure function. They conduct nerves, blood and lymph vessels to viscera. "The peritoneum is also," as Pflüger says, "the matrix of the sexual glands, the ovum a cell of the peritoneum, and the Graafian follicle a constricted-off serous vesicle." The peritoneum is a monster lymph sac, an interstitial space, a slit in the mesoderm which by independent motion of body-wall and viscera has enlarged by coalescing partitions. The mesenteries facilitate motion and function, contraction and expansion of viscera in the peritoneal cavity.

The mesenteries play an important part in hernia. In some 500 autopsies, I found that in over 96 p.c. of subjects the small intestine, having the longest mesentery, could be dragged through the inguinal or femoral canal. Treves asserts that in a normal body the intestine cannot be drawn through the femoral or inguinal rings; but it can scarcely be argued that 96 p.c. of subjects are not normal, or that such a number are afflicted with enteroptosis. It is admitted that often in men and more frequently in women beyond middle life the mesenterium is found sufficiently elongated to herniate. Elongated mesenteries are not frequent in well developed men in the prime of life,

ment, and is degenerating. However, it may be observed that even in the points most distant from the origin and insertion of the omentum, considerable deposit of connective tissue ensheath large blood-vessels, although the small ones have disappeared. The slight remnant of fibrous connective-tissue meshwork found in the middle portions of the omentum is the vestige of the mesodermic mesentery yet following the inevitable course of useless organs.

In the middle portions of the omentum majus and minus are found apertures which Ranvier attributed to the penetration of leucocytes. It appears improbable that these could make penetrations which would ultimately end in such large apertures. These apertures of the omentum are more likely due to the degeneration of the mesodermic mesentery and of both endothelial layers, produced by a process of stretching or rarefaction of tissue.

The blood-vessels are among the most significant factors in the development of the mesenteries. For the mesentery of the digestive tract there are three arteries, which nourish three distinct regions, with their corresponding portions of bowel. The first region is the mesogastrium (which includes the mesoduodenum), and should be named the 'mesenterium gastroduodenale.' It is nourished by the coeliac axis, with its three branches, gastric, hepatic, and splenic arteries. The digestive tract included is the stomach and duodenum. This is the mesentery of the coeliac axis and its branches. His and others claim that the *duodenum transversum* and *ascendens inferior* belong, with their corresponding mesenteries, to the mesenterium and navel loop. The second region of the mesentery is that supplied by the superior mesenteric artery, which extends from the flexura duodeno-jejunalis to the flexura coli lienalis. The digestive tract included in this blood supply is the jejunum, ileum, cæcum, ascending and transverse colon. It includes the business portion of the digestive tract, and forms the navel loop. This region includes the *mesenterium*, *mesocolon ascendens et transversum*. This is the mesentery of the superior mesenteric artery. The third artery of the digestive tract influencing the development of the mesentery is the inferior mesenteric. It nourishes the left mesocolon and mesosigmoid.

and includes the descending colon, sigmoid, and rectum, the faecal reservoirs. This is the mesentery of the inferior mesenteric artery. These three arteries supply three distinct regions of the original mesentery, and by tracing those arteries in the adult, the secondary changes of position and growth in the mesentery may be observed step by step. The mesentery is modified very much by the mechanical influence of its own blood-vessels. The differentiation of the digestive tract into unequal regions begins with the development of the stomach, which may be observed as a spindle-shaped organ at the fourth week. Early in the development of the mesenteries, the three arteries (coeliac, superior and inferior mesenteric) were included in a common sagittally directed mesentery, extending along the dorsal wall from mouth to rectum; but as the alimentary tract grows much more rapidly in length than the body, the tube, in order to make room for itself, begins to form loops or assume a tortuous course. From ontogenetic and phylogenetic researches it would appear that each body segment originally had its intestinal artery, just as it has its intestinal nerve. It has long been known that certain amphibians and reptiles possess a series of small arteries arising from the aorta to supply the digestive tract. This perhaps represents the original conditions, and would remain so while the length of the body corresponded to that of the digestive tract and its mesentery. However, with the advance in scale of life, the length of the digestive tube and mesentery rapidly exceeds the body length, and reduction and concentration of the number of intestinal arterial trunks become a necessity. The intestinal arteries gradually fused into permanent trunks. Hyrtl demonstrated that the reduction of the intestinal arteries occurred in the region of the coeliac axis in *Cryptobranchus Japonicus*, and that similar reductions of intestinal arteries occur in *Menopoma*, Salamander, and Triton. Klaatsch has also shown that fusion of intestinal arteries occurred in amphibians, reptiles, and monotremes. The fusion and reduction has been chiefly with the coeliac and superior mesenteric arteries, for the inferior mesenteric artery appears as a very constant representative. I am inclined to suggest that the hæmorrhoidals from the internal iliacs are representatives of ancient intestinal arteries. The reason for the

permanent trunk of the superior mesenteric artery doubtless lies in its relation to the omphalo-mesenteric vessels, the umbilical vessels, the navel loop, with its extrusion and retraction into the abdominal cavity.

With the growth of the digestive tract, the liver, spleen, pancreas, and genito-urinary organs, the mesenteries assumed three distinct regions, and are supplied by the three arteries. The chief changes in the location of the original sagittal mesentery are due to growth, pressure, coalescence or displacement of the endothelial layers. In the mesogastrium the thinned-out mesoblast originally arose from the middle of the dorsal wall immediately under the aorta, but in the second month it becomes not only displaced to the left, but enormously elongated. The chief factor in displacing and elongating the mesogastrium is the large foetal liver, which forces the stomach into a horizontal position, and at the same time rotates it from left to right (inducing the left vagus to appear on the front wall of the stomach, while the right vagus lies on the posterior wall). The double rotation of the stomach occurred very early, for it displaced the gastric artery from the origin of the mesogastrium to the opposite side of the stomach in the smaller curvature, while the greater curvature in adults is supplied by later developed arteries, the gastro-epiploica dextra and sinistra (from the hepatic and splenic). The hepatic artery, originally intended to supply the lower end of the stomach, has been monopolised by the liver. The splenic artery, originally supplying the middle of the stomach, has been directed to the growing spleen. The forcing of the mesogastrium to the left by the liver forms a depression which gradually deepens and enlarges to an immense bag (*cavum omentalis minoris*), and during the process a large portion of the left wall of the mesodermic mesentery becomes adherent to the dorsal abdominal wall. The mesogastrium contains the spleen and pancreas, the tail and body of which become retro-peritoneal. In the second embryonal month the mesogastrium assumes relations with the transverse and ascending colon, which become gradually enclosed in its blades from right to left.

The right portion of the omentum majus (*omentum colicum Halleri*) may extend along the ascending colon to the entering

the base of the ligamentum latum uteri between its peritoneal mesenteric blades without rupturing the peritoneal membrane. The surgeon can operate on the kidney, ureter, blood-vessels, rectum, bladder, nerves, muscles, and bones posterior to the peritoneum. Simply tearing off the peritoneal mesentery is seldom accompanied by gangrene. In regard to the surgery of the mesodermic mesentery, as in resection of the bowel or penetrating it with the hand or instruments, the subject of blood and nerve supply must be considered. For example, there is danger in removing a kidney if one approaches the kidney from the front by tearing through the mesodermic mesocolon ascendens and descendens. Gangrene from lack of blood supply or paralysis from lack of nerve supply may occur from such proceedings. The mesodermic mesocolon ascendens and descendens should be dissected from the dorsal wall laterally toward the median line, whence the kidney will be free to attack. It must also be remembered, in resecting any viscus from its mesodermic mesentery, that it has a peculiar terminal blood supply—*e.g.*, in the small intestine a set of fine longitudinal and perpendicular blood-vessels exist to supply the bowel; hence the wound of a bowel directly at its mesodermic attachment is very apt to be followed by gangrene, and frequently demands resection. The arrangement of the mesenterium aids to some extent, by indicating that the greatest number of intestinal coils will be in the left half of the abdomen; but so far, we have no tests to locate a small bowel coil by observation nor by experienced sensations of the patient. Definite loops of small intestines do not occupy definite localities of the abdomen. Induced peristalsis, ascending or descending, is insufficient to locate distinctly; the surgeon must trace the loops to landmarks, *e.g.*, the cæcum or flexura duodenojejunalis. In general, the small intestines are arranged in an irregular order, from left to right. In experimenting on dogs with bullets, the greatest damage was done by shots in two directions, viz., (a) a bullet passing from side to side of the abdomen cut from one to fourteen holes in the gut, and generally few holes in the mesentery, as it lies chiefly flat on the dorsal wall; (b) a bullet which passed antero-posteriorly

in the left side, though it cut a less number of holes in the gut, was apt to wound the mesenterium which lies toward the left, producing hæmorrhage.

CONCLUSIONS.

1. One of the chief causes of the complications of the mesentery of the digestive tract is the relations of the anterior end of the colon with its mesoduodenum.

2. There are two kinds of mesenteries: (a) mesodermic, (b) peritoneal. The mesodermic mesentery is a neuro-vascular visceral pedicle, and is constant. A peritoneal mesentery consists of the endothelial layers, and may be a constant or transitory structure.

3. The mesentery of the digestive tract originally arose from the median dorsal line. Its adult arrangement is due to secondary changes, viz., (a) one or both endothelial layers may become displaced; (b) the mesodermic mesentery become fused to the dorsal wall or to another mesentery. The mesodermic mesentery becomes secondarily modified by stretching, causing apertures, as in the middle zone of the omentum majus and minus and at the region of the ileo-colic artery.

4. At the distal border the mesodermic mesentery extends into the parenchyma of the organs, making the life of the organ depend on it. All surgical operations should therefore be performed on it with caution, in order to avoid gangrene.

5. The peritoneal mesentery allows with impunity any aseptic surgical procedure. It protects the peritoneal cavity from the projecting invaginated organs, and facilitates motion.

6. By gradual reduction and concentration of the intestinal (or mesenteric) arteries, man has come to possess three, viz. (a) celiac, (b) superior mesenteric, and (c) inferior mesenteric.

7. The chief rotation of the mesentery of the digestive tube occurs about the celiac and superior mesenteric.

8. The mechanical influence of the blood-vessels on the development and position of the mesentery is considerable.

9. The development of the peritoneum goes hand in hand with the development of the viscera.

10. The position of the adult digestive tube is essentially due to the following factors: (*a*) to its own growth; (*b*) to the growth of neighbouring consistent organs, which limit and direct it; (*c*) to the formation of the mesenterial insertion, and the capacity of motion with which the mesentery endows the bowel.

11. All organs have a mesodermic mesentery, as the duodenum ascending and descending colon. But normally, the duodenum, descending and ascending colon have in the adult no peritoneal mesentery.

THE SENSORY DISTRIBUTION OF THE FACIAL NERVE IN MAN. By A. FRANCIS DIXON, B.A., M.B.

THE study of the connections of the seventh and ninth cranial nerves with one another, and with the fifth nerve in man, has led to one of the most complicated and difficult descriptions to be found in text-books of human anatomy. In many cases a description of these nerves, based upon a rash attempt to establish a manifest similarity in the connections of the various sympathetic ganglia of the head, has added to the confusion; and as the same nerve may receive different names in various parts of its course, the description is often rendered more obscure than is necessary. Our knowledge of the subject can hardly be considered to be in a satisfactory state as long as an almost equal amount of importance is attached to all connecting branches, whether large or small, constant in occurrence or otherwise, irrespective of the functions which they perform. If we admit that importance lies, not in the fact that two nerves are known to communicate, but rather in a knowledge, or conjecture, of what happens in such communication,—that is, which nerve receives fibres from the other—we must regret that, with all their minute accuracy of detail, so many of the ordinary text-books of anatomy and physiology leave the real interest of the matter almost untouched.

It must be admitted that formerly, omitting the results obtained by experiments on lower animals, and by observations in cases of disease, no information regarding the functions of many of the smaller branches or connections of the cranial nerves could be obtained. Within recent years, however, an increase in our knowledge of their mode of development in man, as well as the study of their development and permanent condition in lower forms, has led to the hope that a simpler and more scientific description of these cranial nerves and their chief connections may be substituted for the present elaborate but confusing accounts. It will be found that such studies in embryology and comparative anatomy will not only show what

we may assume to be the functions of the various branches and connections of these nerves, but will also enable us to distinguish between those branches and connections which are primary, or first formed, (these are apparently alone represented in lower forms,) and those which are acquired later, and are more inconstant.

Thanks to the wide-reaching discovery of Professor His—that afferent nerve fibres arise in the embryo as processes of the cells composing the ganglia, while efferent ones are outgrowths from cells within the medullary tube—we possess a useful and certain method of distinguishing between these two great classes of nerve fibres. Not only can we thus determine the functions of many nerves, but we are also enabled to say, from a study of their mode of development, which nerve receives fibres from another where a communication takes place between two nerves or their branches. It is further satisfactory to find that results obtained in this way, in the case of the cranial nerves in man, are borne out by what is known of the conditions of the nerves in lower animals, and are not contradicted by the most reliable pathological and experimental evidence.

To appreciate the difficulties of the subject, as it has been presented by text-books of anatomy and physiology, one has only to study such elaborate works as those of F. Krause¹ on trigeminal neuralgia, and observe the great difficulties he labours under, in an attempt to explain his results, by reference to published descriptions of these cranial nerves, their branches, and connections. In fact, no one description which he quotes is sufficient to explain the results, obtained in his cases, of removal of the fifth nerve roots.

Until quite recent years, very many physiologists, pathologists, and even anatomists have regarded the seventh as a purely efferent nerve, supplying the facial and certain other muscles, as well as providing vaso-dilator fibres for the sub-maxillary and sublingual glands. Such authorities have either made no mention of afferent fibres in connection with the seventh,² or, having recognised taste fibres in the chorda

¹ F. Krause, *Die Neuralgie des Trigeminus*, Leipzig, 1896.

² *Gray's Anatomy*, 1897. Cleland and Mackay, *Human Anatomy*, 1896, pp. 550-552; see also, however, p. 548. Parker and Haswell, *Text-Book of Zoology*, 1897, vol. ii. p. 99 and others.

tympani, they have referred these afferent fibres to the fifth or ninth nerves.¹ The afferent fibres are by these authors supposed to reach the seventh by the great superficial petrosal nerve, by the nerve of Jacobson (small superficial petrosal), and therefore not to be true fibres of the facial itself. Within the last few years, human anatomists have been more and more drawn to the idea that the facial has not only a mixed efferent and afferent distribution, but that the nerve itself is really a mixed nerve, like the trigeminal or ninth nerves, its afferent fibres not being derived from other cranial nerves. They have been led to recognise in the chorda tympani the peripheral distribution of the afferent part of the facial, and in the pars intermedia, with its geniculate ganglion, the afferent root of the nerve. That the fibres of the pars intermedia are continuous with those of the chorda tympani is evidently a fact accepted by the authorities who are responsible for *Die Anatomische Nomenclatur*,² as in this list the name 'chorda tympani' is placed under that of 'nervus intermedius.' It is curious that the name 'ganglion geniculi' is not also placed under the same nerve, instead of being mentioned in the list of the various motor parts of the facial.

Professor His³ and others have for many years insisted on the mixed nature of the seventh nerve in man; and those anatomists who have overlooked the afferent fibres of the nerve, can only have done so from putting too much confidence in supposed conclusive physiological and pathological evidence. It is surprising that so many text-books still hesitate to state emphatically the mixed nature of the seventh nerve, in the manner in which, for instance, they speak of the fifth and ninth nerves. Professor van Gehuchten,⁴ it is true, in a decided manner, separates the efferent and afferent portions of the facial; indeed, he goes so far as to describe the afferent fibres as composing a sensory nerve—the nervus intermedius—distinct from the 'facial,' which is a

¹ Schwalbe, *Lehrbuch der Neurologie*, 1881, p. 853 and p. 356. Macalister, *Text-Book of Human Anatomy*, 1889, p. 607 and p. 664 and others.

² Wilhelm His, *Die Anatomische Nomenclatur*, 1895, p. 89.

³ "Die ersten Nervenbahnen beim menschlichen Embryo," and "Die morphologische Betrachtung der Kopfnerven," *Archiv für Anat. u. Physiol., Anat. Abth.*, 1887.

⁴ *Système Nerveux*, 2^e edition, 1897, p. 531 and p. 518.

purely motor nerve. Professor Gegenbaur¹ also draws attention to the mixed nature of the seventh nerve. In his textbook he says, "Der Nerv führt von seinem Ursprunge an motorische und secretorische Fasern, sensible treten, wie es scheint, durch die Portio intermedia hinzu"; and under the description of the geniculate ganglion, we find, "In dieses Ganglion geht vorzugweise die Portio intermedia ein, die man deshalb auch als Äquivalent einer hinteren Wurzel auffasste." In describing the chorda tympani, he notes the taste fibres present in it, and says these either reach the chorda from the glosso-pharyngeal, or they come from the portio intermedia. Professor Gegenbaur seems to incline to the latter view.

In Professor Thane's² description of the cranial nerves, we find no distinct mention of afferent fibres in the facial until we come to the very useful summary, given after the description of each nerve, where in the case of the seventh we find—"It (the facial) also furnishes, through the chorda tympani, secretory and vasodilator fibres for the submaxillary and sublingual glands; the same nerve would appear to contain the taste fibres from the fore part of the tongue." These afferent fibres in the chorda tympani are also noted in the chapter on the "Morphology of the Nerves," in the tables showing "the constitution of the cranial nerves" and "the segmental nerves of the head." In the latter table we have also a notice of the 'afferent part' of the portio intermedia. On the other hand, in the same chapter, under the heading "Course and Distribution," no mention is made of the sensory distribution of the facial, although the branch of the fifth nerve to the part of the tongue developed from the tuberculum impar is noticed. Of the geniculate ganglion, we are told that its cells resemble those of a spinal ganglion, that it is mainly connected with the portio intermedia, and that "the fibres which proceed from its cells (both proximately and distally) are probably afferent." We also read that, according to many observers, the chorda tympani is, in large part at least, continuous with the portio intermedia. We miss, however, in Professor Thane's description, the clear statement—such as is made, for instance, in the case of the fifth nerve—that the facial is a partly motor, partly sensory nerve.

¹ *Lehrbuch der Anatomie des Menschen*, 1896, vol. ii. p. 467 and p. 469.

² *Quizin's Anatomy*, "The Nerves," 1895, p. 251.

Most of the other English text-books of anatomy,¹ physiology, and pathology ignore or attribute to other sources the sensory fibres of the true facial.

Some time ago, as a result of embryological studies, I drew attention to the fact that the chorda tympani and great superficial petrosal nerves of mammals must be looked upon as true branches of the facial nerve,² and I have further attempted to show that the results of intracranial operation on the fifth nerve roots completely disprove the idea that the sensory (taste) fibres of the seventh are derived from the course of the fifth nerve, and prove incidentally the partly sensory nature of the facial.³ As we have seen above, the fact that the chorda tympani is a sensory branch of the true facial is at present more or less completely recognised by many recent text-books of human anatomy. Up to the present, however, no text-book of human anatomy with which I am familiar urges that the great superficial petrosal nerve in man is a sensory branch of the facial nerve, although a study of its development clearly shows that it arises as such. The more usual accounts of this nerve ascribe to it two kinds of fibres:—motor fibres, passing from the seventh nerve to the ganglion of Meckel, and sensory fibres, coming from the course of the fifth nerve into that of the seventh. According to Professor Thane, for instance, the nerve conveys “fibres from the facial (or portio intermedia) to the spheno-palatine ganglion,” and “others derived presumably from the fifth nerve, which run distally in the facial trunk.” The destination of these latter fibres, which are mentioned on the authority of Penzo, is not stated. The great superficial petrosal nerve is, according to Professor Thane, an “efferent splanchnic” nerve, like the “efferent part of the chorda tympani.” In his summary of the facial nerve he notices

¹ See, for instance, *Gray's Anatomy*, 1897; Macalister, *Text-Book of Human Anatomy*, 1889, pp. 601, 605, and p. 664. Cleland and Mackay, *Human Anatomy*, 1896, pp. 550-552 and p. 548. *A Treatise of Human Anatomy*, edited by Morris, 2nd edition, 1898. In this work the sensory nature of the pars intermedia and chorda tympani is clearly recognised, but “this nerve is regarded as an aberrant fasciculus of the glosso-pharyngeal nerve,” p. 761.

² “On the Development of the Branches of the Fifth Cranial Nerve in Man,” Abstract, *Proc. Roy. Soc.*, 1895, and *Trans. Roy. Dublin Soc.*, 1896.

³ “The Course of the Taste Fibres,” *Edinburgh Medical Journal*, April and June 1897.

that, according to some, the great superficial petrosal supplies the azygos uvulæ and levator palati muscles.

Other authors simply describe this nerve as the motor root of the spheno-palatine ganglion, and we often find it, on the other hand, described under the fifth nerve. It is mentioned in *Die Anatomische Nomenclatur* among the branches of the spheno-palatine ganglion. Professor Gegenbaur¹ describes the great superficial petrosal as carrying motor impulses from the facial nerve to the spheno-palatine ganglion, and he considers it a matter of doubt whether sensory fibres are conveyed by it from the fifth into the course of the seventh. Professor Macalister's view is somewhat similar. Professor van Gehuchten does not consider the great superficial petrosal nerve a branch of the 'nervus intermedius' or sensory part of the facial, but describes it together with the motor seventh. He is evidently, however, not satisfied about the nerve, for he says that although it is generally supposed to carry motor fibres from the seventh nerve to the ganglion of Meckel, for the supply of the levator palati and azygos uvulæ muscles, experiments have shown that these muscles are supplied by the tenth cranial nerve. There never seems to have been much direct evidence to show that the levator palati and azygos uvulæ muscles were supplied by the seventh nerve, and pathologists are now, for the most part, agreed that these muscles are innervated from other sources. The motor functions of the great superficial petrosal nerve have been assumed in many cases by anatomists in order to provide a 'motor root,' or more recently 'splanchnic efferent' fibres, for the spheno-palatine ganglion. Pathological and experimental observations at present afford no evidence of motor fibres in this nerve, and embryological evidence is entirely in favour of the nerve being a sensory branch of the facial (or portio intermedia).

If further evidence in favour of the afferent nature of the great superficial petrosal nerve were wanting, it is to be found abundantly in what is known of the distribution of the afferent part of the seventh nerve in lower animals. Within the last few years comparative anatomists have been enabled to show that a very complete correspondence exists in the distribution

¹ *Lehrbuch der Anatomie des Menschen*, 1896, vol. ii. p. 468.

of the facial nerve and its branches among the various classes of animals, from fishes to mammals.¹

For a long time the fusions which often take place in different groups of animals between, for instance, the seventh and fifth nerves, or between the true seventh nerve and certain nerves of the system of lateral line sense organs, had prevented such correspondence being fully recognised. The accurate study of a large number of adult types and the accumulation of much careful observation has now resulted in the satisfactory isolation, in lower animals, of the nerve corresponding to the facial nerve in man. The true facial nerve in the different classes of fishes has been shown to have a distribution corresponding in a very remarkable manner to that of the ninth nerve and to that of each of the subdivisions of the tenth nerve (see fig. 1). Each of these nerves passes from its superficial origin at the brain to the dorsal limit of one of the gill clefts. In this position it comes into relation with a ganglion, and the nerve divides into two main branches, both of which pass ventrally, one in the arch in front of (cephalic to) the cleft, and the other in the arch behind (caudal to) the cleft. In the case of the seventh nerve, the cleft to which it is thus related is the spiracle. The branch in front of the cleft has received the name 'prespiracular' or 'internal mandibular' nerve, and lies in the posterior part of the mandibular arch, which it follows towards the ventral line. The branch behind the spiracle, on the other hand, is called the 'post-spiracular' or 'hyomandibular' nerve, and lies in the hyoid arch.

In addition to the branches which lie in the gill arches, each of the nerves above mentioned gives off a branch which passes inwards towards the dorsal aspect of the alimentary tube. In the case of the facial, this latter branch has received the name of 'palatine nerve.' Huxley,² Balfour,³ and many more recent writers⁴ have pointed out that the prespiracular (mandibular or

¹ See, for instance, Wiedersheim, *Elements of the Comparative Anatomy of Vertebrates*, adapted from the German by W. N. Parker, 1897, and Wiedersheim, *Grundriss der Vergleichenden Anatomie der Wirbelthiere*, 1898.

² Huxley, *Anatomy of Vertebrate Animals*, 1871, p. 68.

³ Balfour, *A Treatise on Comparative Embryology*, 1881, pp. 376 and 377.

⁴ See, for instance, Strong, "The Cranial Nerves of Amphibia," *Journal of Morphology*, x., 1895. Pinkus, "Die Hirnnerven des *Protopterus annectens*,"

internal mandibular) nerve is the homologue of the chorda tympani of higher animals, and that the palatine branch most probably corresponds to the great superficial petrosal nerve. In fishes, the prespiracular is manifestly a branch of the seventh nerve; it need not apparently communicate with the inferior divisions of the fifth nerve, but it supplies branches directly to the mucous membrane of the floor of the anterior part of the pharynx in the region where the tongue is developed in higher forms. The palatine branch does not necessarily communicate with the superior maxillary nerve, but supplies twigs to the

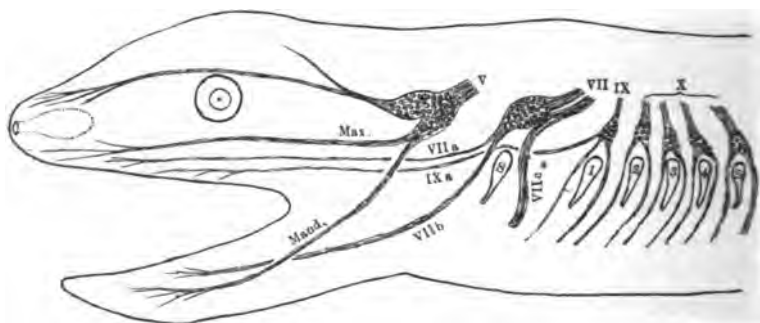


FIG. 1.—Diagram to illustrate the mode of distribution of the fifth, true facial, ninth and tenth cranial nerves in "water-breathing" Anamnia. (Modified from Wiedersheim's *Comparative Anatomy of Vertebrates*, adapted from the German by W. N. Parker.)

roof of the mouth. Both these nerves, prespiracular and palatine, are afferent branches of the facial, connected with the ganglionic root of that nerve. The post-spiracular, on the other hand, is an efferent nerve, like the main trunk of the facial in man, and

Abdruck aus den *Morphologischen Arbeiten* herausgegeben von Dr Gustav Schwalbe, Bd. iv. heft. ii. Cole, "The Cranial Nerves of *Chimæra monstrosa*," *Trans. Roy. Soc. Edinburgh*, 1896. Strong, in his elaborate monograph, not only establishes these homologies in the different animal groups, but by tracing the component parts of the cranial nerves into the brain, he has succeeded in demonstrating many striking and important resemblances in the central connections of the cranial nerves in different groups of animals. Much confusion has arisen from the fact that the component parts of the seventh nerve become separated in different positions in the various animal groups, and different names have often been applied to the same collections of nerve fibres. Cole, in the paper above mentioned, compares the existing descriptions of the seventh nerve and of its branches in different animals, and points out homologies. He draws attention to the marked correspondence between the branches of the facial nerve in fishes and in man.

supplies, just as that nerve in man, the muscles developed in connection with the hyoid arch. The only marked difference between the condition of the true facial nerve in the lower gill-breathing vertebrates and that of the facial in man is, that in man the afferent fibres of the chorda tympani or prespiracular branch, at first follow the course of the post-spiracular nerve; they soon leave this, however, and arching forwards across the tympanum (which developmentally represents the spiracle), they enter the mandibular arch. In typical fishes, on the other hand, both

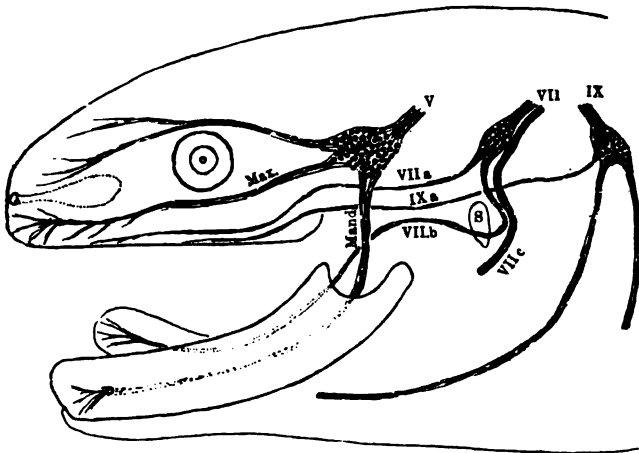


FIG. 2.—Diagram to illustrate the mode of distribution of the fifth, facial and ninth cranial nerves in lower "air-breathing" Vertebrates. (Modified from Wiedersheim's *Comparative Anatomy of Vertebrates*, adapted from the German by W. N. Parker.)

prespiracular and palatine nerves take origin together from the ganglion which represents the geniculate ganglion of man. In lower air-breathing vertebrates the same branches are to be recognised, and it is most interesting to find that the palatine and internal mandibular branches are here again afferent, while the hyo-mandibular is efferent. There is thus a complete correspondence in the typical mode of distribution of the facial nerve and its branches in the vertebrate series with what we must infer from embryological and experimental evidence to be in the case of man.¹ Compare figures 1, 2, and 3.

¹ See graphic summary of recent observations on the cranial nerves by Eduard Könige, "Zur Geschichte der Anatomie der Hirnnerven," Inaugural-Dissertation zur Erlangung der Medicinischen Doctorwürde, Freiburg, 1897.

We must here, however, note that the histological observations of v. Lenhossék¹ in the mouse do not bear out the conclusion that the great superficial petrosal is an afferent branch of the seventh cranial nerve. His preparations, made by Golgi's method, show numerous fibres continued directly from the seventh (or possibly from the nervus intermedius) into the great superficial petrosal through the geniculate ganglion, these fibres being unconnected with the cells of the ganglion. Concerning the great superficial petrosal nerve he concludes—"über die Natur dieses Nerven, ob sensibel oder motorisch, geben meine

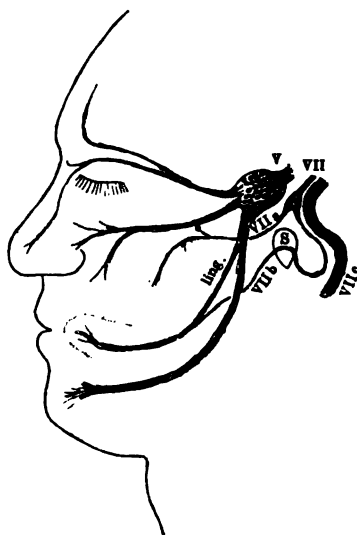


FIG. 3.—Diagram to illustrate the sensory distribution of the facial nerve in man. (Compare with figs. 1 and 2.)

Bilder natürlich keinen unmittelbaren Aufschluss. Die gangbare Ansicht geht bekanntlich dahin, dass der N. petr. superf. major einen echten motorischen Nerven, einem Ast des N. facialis darstellt und man hat ihm sogar die Innervation des M. levator veli palatini und levator uvulae zugeteilt, auf Grund der bekannten anatomischen Forschungen von Bidder . . . u. A. Vom histologischen Standpunkte muss der motorische Character des Nerven in der That als sehr wahrscheinlich bezeichnet

¹ "Das Ganglion geniculi Nervi facialis und seine Verbindungen," *Beiträge zur Histologie des Nervensystems*, 1894, p. 155.

werden." We have seen above, however, that recent observations show that these muscles of the soft palate are not supplied through the great superficial petrosal, from the seventh nerve, and also that, embryologically, the fibres of the great superficial petrosal nerve spring from the cells of the geniculate ganglion. From this, it would seem that the fibres described by v. Lénhossék can at most form a small part of the great superficial petrosal nerve.

The idea that the great superficial petrosal nerve of mammals is a motor nerve is accepted by Professor Gegenbaur,¹ and prevents him homologising that nerve with the palatine branch of amphibia and fishes. As we have seen, Professor Gegenbaur describes the great superficial petrosal as the nerve supply for certain of the muscles of the soft palate.

Dr Gaskell's² observations must also be mentioned here. This author looks upon the nervus intermedius in man, and the corresponding bundles of fine fibres in the seventh nerve of the dog, as "efferent splanchnic" in function. He describes, however, a few large fibres which stand out conspicuously among the smaller ones of the nervus intermedius, and remarks, "I draw attention to this fact (the presence of these large fibres) simply because it is possible that further investigation of these larger fibres may throw light upon the vexed question of the existence of nerves of taste in connection with the seventh nerve." Dr Gaskell considers that the geniculate ganglion represents a "vagrant efferent ganglion of the same kind as the oculomotor ganglion," but says, "it may, however, be more than this, for I have not been able as yet to convince myself that it is free from connection with any group of large fibres, as is the case in the latter ganglion."

Embryological and anatomical investigations have, however, shown that the geniculate ganglion of the facial is a very different structure from the ciliary ganglion. The latter is developed at a relatively late period, and is made up of multipolar nerve cells, while the geniculate ganglion appears early, and is composed of cells resembling those of a spinal ganglion. The fibres of the

¹ *Vergleichende Anatomie der Wirbelthiere*, 1898, Bd. i. p. 812.

² "On the Relation between the Structure, Function, Distribution, and Origin of the Cranial Nerves," *Journal of Physiology*, vol. x., 1889.

afferent branches of the facial nerve (as can be seen very readily in the case of the great superficial petrosal branch, fig. 4) and those of the afferent root grow out from the cells of this ganglion. The root fibres can be traced into the wall of the neural tube, where they form a longitudinally running tract, just as happens in the case of other afferent nerves.¹ Since the

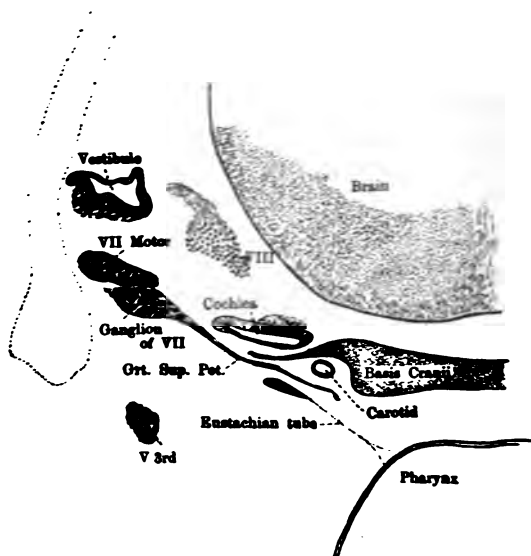


FIG. 4.—Outline of part of a horizontal section through the head of a rat embryo, to show the origin of the great superficial petrosal nerve from the cells of the geniculate ganglion of the facial nerve.

geniculate ganglion corresponds in this manner to the ganglion of a posterior nerve root, we do not require "the evidence of a degenerated ganglionic structure close to the exit of the nerve from the brain" in order to explain the possible presence in man of an afferent distribution of the facial nerve. The facial nerve in man and higher vertebrates possesses sensory branches corresponding to those of lower vertebrates, and there is no evidence to show that these have been replaced by branches of the fifth nerve, as Gaskell has suggested.

Dr Gaskell states that "undoubtedly such nerves as the

¹ His, "Die ersten Nervenbahnen beim menschlichen Embryo," *Archiv für Anatomie und Entwicklungsgeschichte*, Anat. Abth., 1887, p. 375.

chorda tympani and the *petros. superficialis major*, which are known to be largely efferent, spring from this ganglion," i.e., the geniculate ganglion. This statement is, of course, partly correct; but as regards the functions of these nerves, we shall see later that the efferent fibres (vaso-dilator and secretory) which physiologists have discovered in the *chorda tympani* are known to be connected with nerve cells in the neighbourhood of the submaxillary and sublingual glands, but are not known to be connected with other nerve cells, such as those of the geniculate ganglion, outside the brain. Indeed, the anatomical origin of these efferent fibres has been by no means satisfactorily determined.¹

Of especial interest in connection with the afferent distribution of the facial nerve are the observations of Strong² in the tadpole and frog. He has shown that not only the internal mandibular, but also the palatine branch of the seventh nerve, in this animal, supplies taste fibres. His preparations, made by Golgi's method, show the terminal filaments of the palatine nerve, ending in relation to those taste buds which, in this animal, are placed just behind the posterior nares, while the branches of the internal mandibular (*chorda tympani*) end in relation to the taste buds, in the anterior part of the floor of the mouth, in the region of the tongue. Microscopical investigation in the tadpole thus proves that the function of the afferent facial in this animal is similar to what we must consider it to be in man.

In mammals, the anterior portion of the tongue is supplied by two sensory nerves—the lingual branch of the fifth nerve and the *chorda tympani* branch of the seventh. (The former nerve is not present in lower animals,³ and in this connection it is interesting to note its relatively late formation in man.⁴) Intracranial section of the fifth nerve roots does not in man destroy taste sensation in the anterior part of the tongue, hence the *chorda tympani* must be the nerve by which the taste buds

¹ See page 475, this paper.

² "Cranial Nerves of Amphibia," *Journal of Morphology*, 1895, p. 121, pl. viii. figs. 8 and 10.

³ Gegenbaur, *Vergleichende Anatomie der Wirbelthiere*, 1898, Bd. i. p. 808.

⁴ Dixon, "The Development of the Branches of the Fifth Cranial Nerve in Man," *Trans. Roy. Dub. Soc.*, 1896, vol. vi. p. 54.

are innervated. Here I would specially like to refer to the cases reported by L. MacTiffany and by Krause, as well as to a case which, owing to the kindness of Mr Lynn Thomas, I have had an opportunity of examining personally. L. MacTiffany¹ has published notes of the condition of three patients in whom he has removed the intracranial portions of the second and third divisions of the fifth nerve, and the part of the Gasserian ganglion attached to them, tucking at the same time the distal ends of the nerves into their foramina. In the first case, examined thirteen months after the operation, he says, "taste on the tongue is not interfered with." The method of conducting the investigation was as follows:—"The tongue is drawn beyond the lips and securely held. Its surface was dried with a soft rag, and a drop of warm water, containing sugar or salt in solution, was put on the part of the tongue entirely without sensation, either of general touch, heat, or cold. Almost instantly the patient was able to tell whether sugar or salt was put on her tongue, and this, of course, without drawing the tongue into the mouth, but while the tongue was firmly held outside the lips."

In the second case, a similar condition was found to exist four months after operation; while in the third case, although the patient stated that taste was the same as always, still the difference between salt and sugar is not recognised when applied on the tongue held beyond the lips.

The results of Krause² are not so uniform. In some of his cases taste was lost on the anterior parts of the tongue, while in others it was retained after complete removal of the Gasserian ganglion and the fifth nerve roots. I have attempted, in another place, to show that these varying results most probably depend on slight differences in the amount of damage done during the operation to neighbouring structures, and have called attention to the close proximity of the geniculate ganglion of the facial to the Gasserian ganglion in man.³ In this connection, it is of interest to note that, owing to the more

¹ "Intracranial Neurectomy and Removal of the Gasserian Ganglion," *Annals of Surgery*, 1894, p. 51.

² "Die Neuralgie des Trigeminus," 1896.

³ *Edinburgh Medical Journal*, June 1897.

extensive raising of the dura mater from the floor of the middle cranial fossa in order to remove the entire Gasserian ganglion, as Krause had done, the underlying geniculate ganglion and its branches run a greater risk than when the branches alone of the Gasserian ganglion are removed.

In Mr Lynn Thomas' case, two months after an operation, in which the right superior and inferior maxillary nerves were divided within the cranium, the patient tastes equally on both sides. He is able to distinguish sugar and salt on the anterior part of the right side of the tongue, over an area which is otherwise perfectly anæsthetic. These substances can be recognised, when placed in solution upon the tongue, before the patient withdraws the tongue into the mouth.¹

In Mr Thomas' case, as in several others that have been recorded, the soft palate retains its sensibility after section of the fifth nerve trunks. We must, I believe, attribute the conveyance of sensory impulses in these cases to branches either of the ninth or of the seventh nerve, viz., to the small superficial petrosal branch of the ninth nerve, or to the great superficial petrosal branch of the seventh. The mode of development of the small superficial petrosal shows it to be undoubtedly an afferent nerve, and at present we have no direct anatomical evidence that it contains taste fibres as well as those of common sensation (see, however, p. 473). The intimate connection of the small superficial petrosal nerve, in part of its course, to the dura mater of the middle cranial fossa, possibly explains why in certain cases of intracranial operation the soft palate loses its sensibility.

We may, perhaps, conclude from the distribution of the corresponding branch—palatine—in lower animals, that the great superficial petrosal nerve supplies in man the taste buds of the soft palate. At present we have no direct evidence that the seventh nerve contains fibres of common sensibility. Its chorda tympani branch certainly does not, as is clearly seen

¹ Since this paper was written, through the kindness of Dr Lynn Thomas, I have been enabled to observe the condition present in a second of his cases in which he has divided intracranially the superior and inferior maxillary divisions of the fifth nerve. In this case the patient, before operation, possessed very acute taste sensibility, which after section of the nerves mentioned is quite unimpaired both on the tongue and on the soft palate.

in those cases in which the central connection of the lingual nerve fibres with the brain is destroyed.

If we are right, not only in looking on the facial nerve as a partly sensory nerve, but in considering that its afferent fibres are concerned in conveying taste impulses, we are brought into direct conflict with the conclusions of many pathologists¹ and physiologists.² I regret that, with the literature at my disposal, I have been unable to obtain accounts of very many of those pathological cases which are supposed to prove the non-existence of taste fibres on seventh nerve.

None of the cases, however, which I have been able to obtain accounts of, seem to me to be at all conclusive. For instance, in a case described by Dr Gowers³ as lending weight to the idea that the fifth nerve conveys the taste impulses from the tongue, the lesion which has caused loss of taste is undoubtedly not confined to the fifth nerve roots. Not only is the sixth nerve paralysed, but the seventh nerve is also affected, as is shown by the wasting of the facial muscles. Dr Gowers attributes this latter symptom to nutritive disturbances, due to implication of the fifth nerve. That this is very unlikely to be the true explanation is, however, shown by the fact that in cases where the Gasserian ganglion has been removed, wasting of the facial muscles has not ensued.

Dr W. A. Turner⁴ quotes from a case described by Ferguson in the *Medical News*, Philadelphia, 1890, and says it "appears to be a crucial case upon the course of the taste fibres for the anterior two-thirds of the tongue, if the facts are correctly stated." I have been unable to see the original description. Dr Turner, however, says that "a small exostosis was observed post-mortem to press upon and divide the left Vidian nerve.

¹ See, for instance, Gowers' *Diseases of the Nervous System*, 1893, vol. ii. p. 224.

² Foster, *Text-Book of Physiology*, 1891, part iv. p. 1404; Starling, *Elements of Human Physiology*, 1895; Stewart, *Manual of Physiology*, 1899; among many others.

³ "A Case of Paralysis of the Fifth Nerve," *Edinburgh Medical Journal*, Jan. 1897, p. 37.

⁴ "Note on the Course of the Fibres of Taste," *Edinburgh Medical Journal*, Sept. 1897, p. 261. See also "Facial Paralysis and the Sense of Taste," *Edinburgh Hospital Reports*, vol. iv., 1896, p. 334, where Dr Turner concludes that the taste impulses reach the brain either by the superior maxillary or inferior maxillary branch of the fifth nerve.

During life complete loss of taste had existed upon the anterior two-thirds of the left side of tongue, while the posterior third, the fauces, and the soft palate retained the sense of taste. Subsequent microscopic examination showed degeneration of the great superficial petrosal nerve, which was traceable into the ganglion geniculi facialis, and to pass through the facial trunk as far as the chorda tympani, through which it was traced to the lingual nerve." This case certainly seems to prove that the sensations of taste from the anterior two-thirds of the tongue depend upon the sensory part of the facial nerve (*i.e.*, *nervus intermedius* and its branches), but one can scarcely believe, from what we know of its mode of development, that mere division of the Vidian nerve would cause degeneration of the chorda tympani. It seems more probable that degeneration of the cells of the geniculate ganglion may have been in this case primary, and have been followed by degeneration of the chorda tympani and superficial petrosal branches of the ganglion. The fact that in many cases complete removal of the Gasserian ganglion and fifth nerve roots has not led to degeneration of the chorda tympani (as is shown by the retention of taste sensation on the anterior two-thirds of the tongue), favours the idea that in Ferguson's case, as reported by W. A. Turner, the degeneration traceable through the geniculate ganglion into the chorda tympani, was not dependent simply on the section of the connection between the seventh and fifth nerves.

The existence of the sense of taste on the soft palate in this case may indicate that the ninth nerve supplies some of the taste buds on the soft palate, if we assume that all the fibres of the great superficial petrosal were involved in the lesion: this has not, however, been demonstrated anatomically.

With regard to pathological observation, although the balance of evidence may here tend towards the idea that the taste fibres belong to the fifth nerve as Dr Turner states, still absolute proof is wanting. There are many cases recorded in which taste has been lost on the anterior part of the tongue, where the symptoms which presented themselves receive as satisfactory an explanation by assuming a lesion of the seventh nerve roots rather than one of the fifth nerve.¹ In any event, the small balance of evidence

¹ An interesting case recorded by Dr Gibson and Mr Cattanaoh, "On the VOL. XXXIII. (N.S. VOL. XIII.)

in favour of the fifth nerve, derived from pathological observation, does not seem important when weighed against the evidence in favour of the seventh, derived, for instance, from a study of cases in which the fifth nerve roots have been divided intracranially.

Physiological experiments have demonstrated the presence of other fibres besides taste fibres in the 'chorda tympani' of mammals. Much attention has been paid to these fibres, which, leaving the tract of the lingual nerve, are destined for the submaxillary and sub-lingual glands.

By Professor Stewart,¹ the term 'chorda tympani proper' is restricted to the nerve formed by these 'vaso-dilator' and 'secretory' fibres as they leave the chordo-lingual nerve to reach the submaxillary and sublingual glands. Speaking of the connections of the vaso-dilator fibres with the central nervous system, he says that the outflow of vaso-dilator fibres takes place through the anterior nerve roots; some emerging with the roots of the cranial nerves. "It is believed that every vaso-motor fibre is interrupted by one, and only by one, ganglion cell between the cord and the blood-vessels." If this latter statement proves to be true, the vaso-dilator fibres of the 'chorda tympani' of physiologists cannot represent the early developed chorda tympani of man, or the corresponding prespiracular nerve of lower vertebrates, since their ganglionic connections lie in the cells in the neighbourhood of the submaxillary and sublingual glands, and not in the geniculate ganglion of the facial nerve. The secretory fibres of the chorda tympani also become connected with nerve cells in the region of the glands which they supply, and they are not known to be connected with any other nerve cells outside the central nervous system. Many other physiologists,² just as Professor Stewart, consider that the

'Coincidence of Facial Paralysis with Acute Anterior Poliomyelitis,' *Edinburgh Hospital Reports*, 1896, illustrates the extreme difficulty often experienced in determining the causation of such clinical symptoms as loss of taste.

¹ *A Manual of Physiology*, 1899.

² Professor Starling considers the chorda tympani, in as far as it is composed of secretory and vaso-dilator fibres, to be a branch of the facial nerve, while, on the other hand, "the fibres of taste which are said to run in this nerve are probably derived from the glosso-pharyngeal" (*Elements of Human Physiology*, 1895, p. 401, and p. 210, fig. 76). Professor Foster also comes to the "provisional conclusion" that although gustatory fibres may be found in the chorda tympani

only fibres of the chorda tympani that undoubtedly belong to the seventh nerve are the vaso-dilator and secretory ones mentioned.

With regard to the 'chorda tympani' of authors with such views, we must note that the 'chorda tympani' nerve which they describe is not the nerve which in lower animals springs from the ganglion of the facial, and which supplies the taste buds on the anterior part of the floor of the mouth. The 'chorda tympani' of these physiologists is not a nerve of taste, since according to them the fifth or ninth nerve supplies the taste buds on the anterior part of the tongue. The fibres which constitute this 'chorda tympani' end finally in nerve cells (multipolar?) in the region of the hilum of the submaxillary gland, or in ganglion cells in connection with the nerves of the sublingual gland. At present, nothing seems to be known of the mode of development of these 'secretory' and 'vaso-dilator' fibres in the chorda tympani; their representatives in lower vertebrates are not known; there is no evidence to show that their origin is similar to that of the taste fibres, which pass in the chorda tympani branch of the facial to the lingual nerve in man, and form the homologue, as we have seen, of the internal mandibular or præspiracular nerve of fishes.

It is a remarkable fact that physiologists recognise these 'secretory' and 'vaso-dilator' fibres in the seventh nerve with the greatest certainty, while they in many cases deny to the same nerve afferent fibres—most or all of which appear to be connected with taste—of which, as we have seen, we possess anatomical evidence. We have little or no anatomical evidence to show why we should refer the fibres which pass to the submaxillary and sublingual glands, and whose functions have been determined by physiologists, to the facial nerve, rather than to the sympathetic system. It is noteworthy, for instance, that while the vaso-dilator fibres which leave the lingual nerve in the 'chorda tympani' (for these glands) are referred to the seventh nerve, yet those which remain in the lingual tract, and are distributed to the vessels of the tongue, are referred by physiologists to the

they really belong to the fifth nerve. Secretory and vaso-dilator fibres are, however, present in the chorda tympani branch of facial (*Text-Book of Physiology*, part iv. p. 1404. See also fig. p. 397, part ii.)

cervical sympathetic.¹ Our knowledge concerning the morphology of the sympathetic system is at present in so unsatisfactory a state, that it seems useless to speculate regarding it until more facts have been collected concerning the manner in which it is developed. Assuming that it is correct to relegate the various sympathetic ganglia of the head to particular cranial nerves as 'vagrant ganglia,' we have even then no certain evidence to show whether the submaxillary ganglion (or its cells) should be considered in connection with the fifth or with the seventh nerve.

One cannot help remarking in this connection that many statements, based largely upon theoretical considerations, have not rendered more clear the facts known regarding the morphology of the cranial nerves, and their connections with the sympathetic. If we are right in drawing a sharp distinction between sympathetic ganglia and the ganglia of the posterior nerve roots—as from their mode of origin in the embryo and from their histological character in the adult seems justifiable—it is certainly inexpedient to call the ganglion of the seventh nerve in any sense a 'sympathetic ganglion,' simply because the fibres which spring from it 'innervate visceral surfaces.'² If the term 'splanchnic' or 'visceral' afferent is advantageously applied to certain parts of the distribution of the cranial nerves, as has been suggested by Gaskell, it seems unwise to go further and apply the term 'sympathetic' to the ganglia from which these nerves spring. For instance, if the afferent distribution of the facial is to be considered 'sympathetic' because it has to do with parts derived from the splanchnopleure, we must also apply the same term to the lingual branch of the fifth nerve, since it supplies the same part of the tongue as the chorda tympani, and thus the Gasserian ganglion will also be partly a

¹ Starling, *loc. cit.*, p. 400.

² Cole, "Reflections on the Cranial Nerves and Sense Organs of Fishes," *Trans. Liverpool Biol. Soc.*, vol. xii., 1898, and "Observations on the Structure and Morphology of the Cranial Nerves and Lateral Sense Organs of Fishes, with special reference to the genus *Gadus*," *Trans. Linnean Society*, vol. vii. part v., Oct. 1898. In this latter paper we read that the facial ganglion of the cod is "physiologically and morphologically comparable to a sympathetic ganglion, since the fasciculus communis fibres belong essentially to the sympathetic system." Why the term 'sympathetic system' should be used in reference to this tract formed within the brain, by entering afferent nerve fibres, it is difficult to understand.

'sympathetic' ganglion. At present, however, we have no evidence to show that the Gasserian ganglion is made up of two portions which are morphologically distinct; and Dr Gaskell himself, in his diagram of the arrangement of the segmental cranial nerves, indicates the entire sensory part of the fifth nerve, with the exception of a small portion of the ophthalmic division, as somatic afferent.

Unless we are to completely alter the use of the term 'sympathetic ganglion,' it is most confusing to apply the name to ganglia which are essentially composed of cells of spinal ganglion type. The researches of Disse,¹ v. Lenhossék,² Dogiel³ and others have indeed shown that careful search may often reveal the presence of a very small number of cells resembling multipolar cells, of typical sympathetic ganglia, in the spinal ganglia; still, these observations do not yet seem to justify us in homologising ganglia in whose general histological structure and embryonic history the greatest difference are to be noted.

Those attempts which have been made to reduce the various cranial nerves and their 'stationary' and 'vagrant' ganglia to a uniform type seem to be rash when we find that such attempts depend upon the substitution of multipolar nerve cells for those known to be of spinal ganglion type, to suit the pleasure of the author.⁴

With our present knowledge of their mode of development, it is most confusing to speak of the central origin within the brain of afferent nerve fibres, or to say of the pars intermedia that it takes origin from the fasciculus communis (funiculus solitarius),⁵ or from the ninth nerve nucleus,⁶ since one might just as well describe the afferent fibres of the various spinal nerves as taking origin from the posterior columns of the spinal

¹ "Über die Spinalganglien des Amphibien," *Verhandl. d. Anat. Ges.*, 1893, p. 201.

² "Zur Kenntnis der Spinalganglien," *Beiträge zur Histologie des Nervensystems*, 1894, p. 129.

³ "Der Bau der Spinalganglien bei den Säugetieren," *Anatomischer Anzeiger*, Bd. xii., June 1896, p. 140.

⁴ See, for instance, "Plan of the arrangement of the constituent fibres of the cranial nerves in the bulb," *Quain's Anatomy*, vol. iii. part ii. p. 386, fig. 241.

⁵ Cole, *Trans. Linnean Society*, vol. viii. Oct. 1898. Cleland and Mackay, *Human Anatomy*, 1896, p. 550.

⁶ See, for instance, *Morris' Anatomy*, 1898, p. 761, *loc. cit.* p. 145.

cord, or as springing from the cuneate and gracile nuclei of the medulla.

CONCLUSIONS.

The facial nerve in man is in a condition comparable with that which obtains in lower animals. The nerve closely resembles in its distribution what has been called a 'typical branchial nerve,' or as Cole forcibly states, 'the mammalian facial . . . bears in its present-day structure undoubted evidence of its descent from the branchial facial nerve of a fish.' The facial consists of a motor and of an afferent portion, and is the nerve developed in connection with the spiracle (or ear cleft). The motor portion of the nerve lies behind the first cleft, in the hyoid arch, and supplies the muscles developed in connection with this arch, while the afferent branches which spring from the cells of the ganglion of the facial are distributed to structures developed in connection with the wall of the anterior portion of the pharynx. These afferent branches in mammals are the chorda tympani and the great superficial petrosal nerves. Both these nerves are probably entirely or almost entirely composed of taste fibres. The chorda tympani nerve certainly does not convey common sensory impulses, but in the case of the great superficial petrosal this has not been proved.

The vaso-dilator and secretory fibres, which have been shown by physiologists to exist in the mammalian chorda tympani, do not form the whole of that nerve, nor do these fibres represent the primitive chorda tympani or prespiracular nerve of lower vertebrates. The chorda tympani is the primitive nerve supply of the anterior part of the floor of the mouth. With the development of the mammalian tongue the lingual branch of the fifth nerve is formed; but, even in mammals, this latter nerve arises at a considerably later time, embryologically, than the chorda tympani.

These facts regarding the seventh nerve seem to be anatomically of primary importance, since they are supported by embryological observations in man, by the results of comparative anatomists, as well as by direct experimental evidence.

ARCHÆOLOGIA ANATOMICA.

IV.

POUPART'S LIGAMENT.

THERE is scarcely any one of the eponymous structures in the human body whose name is so firmly fixed in anatomical literature as the band which bears the name of Poupart. In English, French, German, and Russian books of the present day this name is almost universally used; and although the Basel nomenclature proposes to supersede it by the term *ligamentum inguinale*, yet the older name is so well established, not only in anatomical but also in surgical literature, that it is improbable it will ever be displaced.

And yet few men have attained immortality on such easy terms as François Poupart, whose short note upon the ligament was apparently regarded by his contemporaries as of so little import that Fontenelle, in his funeral oration, when enumerating his works, never refers to it. Neither does Niceron in his memoir in vol. xi. of his *Histoire des Hommes Illustres*, p. 269, nor the author of his memoir in the *Biographie Universelle* (suppl. vol. 77).

The structure which we now call Poupart's ligament was certainly indicated by Vesalius, who speaks of the tendon of the *obliquus descendens* as stretching from the anterior spine of the ilium to the pubes nearly as far as the symphysis "non quod illo ductu ab ilium osse ad pubis ossium usque commissuram ossi inseratur, sed duntaxat, ubi os ex carne reperit. Quà enim duo femur flectentes muscoli, super coxendicis et pubis os deorsum proriepunt, obliquus hic musculus ossi non implantatur."

Gabriel Fallopius is much more precise and explicit. In describing the same part of the same muscle he says "quousque ad ilium ossis spinam devenientes illi innascantur, inde ad pubis ossa inseruntur ligamento quodam innixi, quod ab extraneo apice spinæ ilium ad pubis ossis acutum pertinet: ab illo N

musculi isti tanquam ab osse suffulciuntur, quæ N ossis regio ibi est, à musculis duobus flexui inservientibus occupatur."

He again refers to this unnamed structure, which, after the manner of his time, he designates N, when discussing the abdominal recti, which he says are covered by the tendons of the oblique muscles to where these N of the oblique muscles descend to the sides of the recti. (*Instit. Anat.*, Venice ed., 1606, i. p. 2-3).

Again, in his *Observationes Anatomix*, addressed to Peter Manna (same ed., i. p. 70), when discussing the actions of the abdominal muscles, he says that the attachment of these below is not to the bone, but to that strong ligament which runs from that spine (of the ilium¹) to the pubic bones. In the next paragraph, on the same page, he notes that the cremaster is attached "illo ligamento, cuius mentionem nuperrime feci."

In passing over the numerous references, implicit or explicit, during the seventeenth century, it is worth noting that it is sometimes referred to as the *ligamentum pubis* (see Cowper, *Myotomia Reformata*, 1694).

In 1705 M. Poupart made an oral communication to the Royal Academy of Sciences in Paris, of which a note is preserved on p. 51 of the History of the Academy for that year. The note is a short one:—"M. Poupart a parlé de deux gros Ligaments ronds, fort visibles, puisque dans les grandes personnes ils sont longs de plus d'un demi-pied, et dont cependant les Anatomistes n'ont point traité, apparemment parce qu'ils n'en ont pas connu les usages. Ils sont attachés par un bout sur la crête de l'Os des Iles, par l'autre bout sur la crête de l'Os Pubis, et la milieu porte a faux. Ils font la fonction d'os en cet endroit, car ils soutiennent les trois grands Muscles de l'Abdomen, c'est-à-dire, l'Oblique externe, l'Oblique interne, et le Transverse. Leurs fibres tendineuses à peu près paralleles entre-elles vont s'attacher à ces Ligaments. Ils sont situés immédiatement au dessous des Anneaux.

"La pensèe de M. Poupart est qu'ils peuvent soutenir et rompre en partie l'impulsion que de grandes toux, des sauts violents, etc.,

¹ It will be noted that these classic anatomists always use the title *os ilium* or *ossa ilium* for the hip bone, *ilium* being the genitive plural of the obsolete *ile* the flank. *Ossa ilium* means the bones of the flank. Our common use of the word, as if it were a neuter nominative, is therefore a barbarism.

donnent aux Intestins, et par-là les empêcher de s'insinuer entre les Anneaux, et de former des Hernies. De plus ces Ligaments tenant lieu d'Os, quelques Os la Nature eût mis à leur place, le Ventre en auroit en moins de liberté de s'étendre, sur tout dans les grossesses. Par ces raisons, M. Poupart appelle ces deux Ligaments *Suspenseurs de l'Abdomen*."

That is all. We are bound to believe M. Poupart that he was unacquainted with Fallopius' description, but his comparison to a bone and his idea of its function are singularly like that author's "tanquam ab osse suffulciuntur."

The description by Poupart might easily have been overlooked but for the acuteness of the great anatomical critic of Padua, Giovanni Battista Morgagni. In the third series of his *Adversaria Anatomica*, published in 1717, he calls the attention of Mangetus to these two ligaments which Poupart had described. Morgagni was acquainted, as he tells us here, with the works of the old anatomists in which these are described, and he proceeds to demonstrate that these are not peculiar ligaments at all, but only the lower borders of the tendon of the obliquus externus: "Fiunt namque ex fibris quæ proximis in continuato tendine sunt parallelæ, eadem cum ipsis figura, crassitie, colore, consistentia, eademque demum; quod potissimum attendendum est; cum fibris musculi carneis continuatione," etc. (*Animadversio*, i., Venice ed., 1767, p. 67).

It certainly was not owing to any Chauvinism of the French anatomists that the name of Poupart became attached to this ligament. Portal says that both Vesalius and Fallopius have described the inguinal ligament, and that it is without any reason that people accord the discovery to Poupart (*Cours d'Anat. Méd.*, 1803, ii. 143). Winslow calls it the ligament of Fallopius, and denies its independence; so does Lieutaud; Cruveilhier and Cloquet call it the ligament of Fallopius or Poupart; so do Lauth of Strassburg and Bichat (1846, ii. p. 145). One French biographer says that his description is neither new or exact.

Among the English eighteenth century writers, it is also called the inguinal ligament, crural arch, ligament of Fallopius, or ligament of Poupart; but when we come to the school of surgical anatomists who were especially concerned with the anatomy of

hernia, we find that they all call it Poupart's ligament; Sir Astley Cooper, Liston, Gay, Colles, and all of their period, have but the one name for it, and from them we have inherited it.

But although Poupart cannot claim the credit of having been the original describer of the structure, yet the perpetuation of his name is a just tribute to a deserving man. Born of humble parents, at Mans, in 1661, and being one of a large family, in spite of many obstacles he rose to a position of honour and reputation. His father originally designed him for the Church, and put him under the instruction of the Fathers of the Oratory, but patristic studies and scholastic philosophy were not much to his taste. Having obtained access to the works of Descartes, his interests were awakened in practical science and medicine, and to pursue these he left home and obtained a post as tutor in Paris.

After some time, however, he found that his duties in this capacity interfered with his studies, so he resigned his appointment, and lived in dire poverty, wholly devoted to learning. He presented himself for examination at the Hôtel Dieu and passed brilliantly, astonishing the examiners with the extent of his knowledge, although he had had no opportunities of practical work. Having worked under Duverney, he ultimately became a member of the Royal Academy of Sciences, and Doctor of Surgery of the University of Rheims.

Poupart was no mere specialist: he attended lectures on geometry, and gained a respectable knowledge of mathematics. He also became a pupil of De la Hire in architecture, and studied other branches of knowledge; but his health had been injured by his early privations, and he died in his 48th year, in 1709. To the last his life was a struggle with circumstances, and he died, as he had lived, in poverty.

He left behind him about a score of published papers, some in the *Journal des Sçavans*, some in the *Memoirs of the Academy*. These were on a variety of subjects,—*Des Écumes Printanières* (cuckoo spit); *Sur le Formica leo*; *Dissertation sur l'Apparition des Esprits*; *Mémoires sur les Insectes Hermaphrodites*, etc. But it is strange that none of the three biographers refer to the short paper on which his permanent reputation rests, which has

made his name familiar to anatomists of every land at the present day.

In the short biographic note in Rees' *Cyclopædia* he is credited with the authorship of a *Dissertation sur la sangue*. The author has probably confounded his *Histoire Anatomique de la sangsuë* with a much older work which was written a hundred years before François's day. Its whole title is *Traité la saignée contre les nouveaux Erasistrateens qui sont en Guyenne*, and it was published at La Rochelle in 1576 by one Olivier Poupart, a native of St Maixent in Poitou. Two of Poupart's papers appear in the Philosophical Transactions, one on dragon-flies and one on leeches.

ANATOMICAL NOTES AND QUERIES.

26. ABNORMAL ARTICULATION BETWEEN THE HEAD OF THE ASTRAGALUS AND THE CUBOID BONE. — The accompanying diagrams show three examples of the abnormal articulation. In case 1, the condition was unilateral; in cases 2 and 3, it was, as shown, bilateral. In each case the facet on the cuboid entered into the joint between the internal and the external calcaneo-scaphoid ligament, but in specimen 3 the internal ligament has been removed. In each case the arch of the foot was good, and the scaphoid and cuboid bones met in diarthrodial junction.

Attention was called to this abnormal articulation by Bland Sutton (*Anat. Soc. Proc.*, May 1892), and instances were mentioned by Thane and Macalister (*ibid.*).

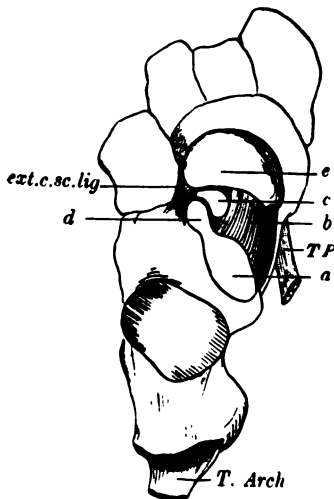


FIG. 1.



FIG. 2.

Fig. 1. Astragalus, with facets for (*a* and *d*) calcaneum; (*b*) calcaneo-navicular ligament; (*c*) cuboid; (*e*) navicular.

Fig. 2. The bones surrounding astragalus, showing its bed.

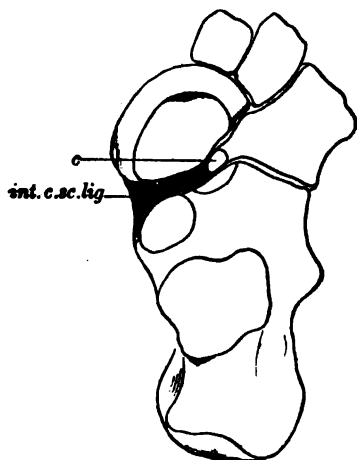


FIG. 3.

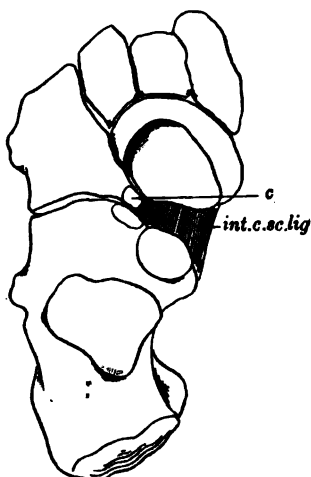


FIG. 4.

Figs. 3 and 4. Right and left series of tarsal bones in specimen 2, showing astragalus bed; *c* is the facet on the cuboid for the astragalus.

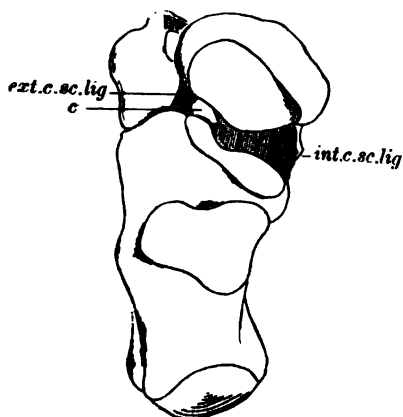


FIG. 5.

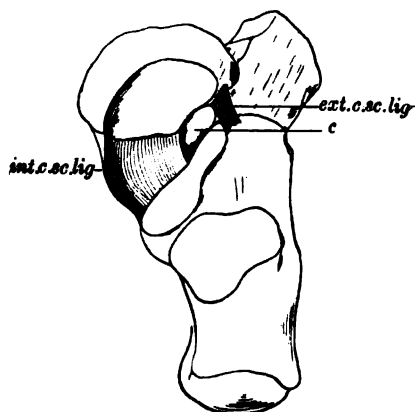


FIG. 6.

Figs. 5 and 6. Right and left series of tarsal bones in specimen 3; *c*, as before.

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27. CERVICAL RIB, RECOGNISED DURING LIFE.—Dr Morison described a case in which a lump at the root of the neck was

shown by skiagraphy to be a cervical rib, over which the sub-clavian artery ran. (*Brit. Med. Jour.*, Dec. 31, 1898, p. 1933.)

28. SKIAGRAPHY OF EPIPHYSES.—In Mr Poland's excellent monograph on *Traumatic Separation of the Epiphyses* (Smith, Elder & Co., 1898) there are good figures of the bones of the hand, in different stages of development.

29. RELATIONS OF THE SKELETON OF THE FACE TO THE SUPERFICIAL SOFT PARTS.—Professor Kollmann's most interesting reproduction of the surface appearance of the head and face of a female of the neolithic period, from Auvernier, illustrates a mode of studying extinct races which might with advantage be extended. The papers in the *Anatomischer Anzeiger*, xv. p. 165, and *Correspondenz-Blatt der Deutschen Anthropologischer Gesellschaft*, 1898, p. 116, are worthy of careful perusal.

30. The following papers on Osteology are interesting:—

PAPILLAUT on numerical variations of the lumbar vertebra in man, *Bull. Soc. d'Anthropol. Paris*, ix. p. 193.

ROMITI on the processus marginalis, *Atti d. Soc. Toscana di Sc. Nat.*, v. 12.

MIGNON on skiagraphy of a case of double thumb, *Bull. Soc. Anat. Paris*, lxxiii. p. 211.

PÉRAIRE, skiagraphy of a case of polydactyly, *ibid.*, lxxiii. p. 151.

ARBUTHNOT LANE on some points on the anatomy of the first rib and hip-joint, in a paper "Fractures and their Treatment," *Clinical Journal*, xiii. pp. 129, 152.

HULTKRANTZ on congenital defect of the clavicle, and cranial anomalies associated with it, *Anat. Anzeiger*, xv. p. 237. This paper is interesting in connection with Dr Terry's paper in this number of this *Journal*.

HÜLSEN on the specific gravity, elasticity, and hardness of bone. Published in the *Journal* of the St Petersburg Biological Laboratory, in Russia, accompanied by a German abstract.

SCHMIDT, studies in the comparative anatomy of the mechanical structure of bone and its heredity, *Zeitsch. für Wissensch. Zoologie*, lxxv. p. 65.

POPOWSKY on bifurcated extremities of ribs, which he regards as the traces of suppressed segments, *Anatomischer Anzeiger*, xv. 284.

BECKER on the skeleton of a eunuch, *Arch. f. Anat. u. Phys.*, 1899, 83.

31. MYOLOGY OF THE HAND.—The Boylston Prize Essay, by Dr J. F. Walsh, of Camden, N.J., is a careful piece of work, the



DR GRIFFITH ON THE ANOMALOUS ARM-MUSCLE.

[To face p. 501.]

most important part of which is the detailed examination of the tendons of the interossei and the exact manner of their insertion. The author, however, does not refer to the work of Ruge, Kupffer, Cunningham, or Hepburn on the nature of the flexor brevis pollicis, nor does he give statistics as to the frequency of the different conditions which he describes, nor does he refer to the innervation of these muscles. As far as it goes, it is the record of painstaking dissections.

32. The following papers are worthy of note:—

GÉRARD on duplicity of the left sternomastoid, *Bibliographie Anat.*, vi. p. 214.

SHERRINGTON on the reciprocal innervation of antagonistic muscles, *Proc. Roy. Soc.*, lxiv., 1898, p. 179. A study of the actions of the orbicularis palpebrarum and levator palpebræ superioris muscles, in which it is recorded that, under certain conditions, in blinking with one eye, the other lid dropped a little on account of inhibition of the tonus of its levator palpebræ.

ROSENFELD on the comparative anatomy of the tibialis posticus muscle, *Anatomische Hefte*, Wiesbaden, xxxvi. p. 359.

ROSENFELD on the shoulder-ligaments of men and some mammals (*ibid.*, p. 339).

CAVALIE, innervation of the diaphragm by intercostal nerves in mammals and birds, *Journ. de l'Anat. et de la Physiol.*, xxxiv. p. 642.

CHRISTIAN on two instances of the musculus sternalis, *Johns Hopkins Hosp. Bull.*, 90-91, 1898, one innervated for the anterior external thoracic, the other for the anterior cutaneous of the 3rd interosseous.

MACCALLUM on the growth of the human sartorius muscle (*ibid.*, 1898). The adult sartorius has about 140,000 fibres in its mid-cross-section, the foetus at birth about 120,000; a foetus of 130 mm. has 45,205, and one of 74 mm. has 6509.

MALL, development of the ventral abdominal walls in man, *Journal of Morphology*, xiv. 347.

ESCHWEILER on the comparative anatomy of the muscles and the topography of the middle-ear in certain quadrupeds, a valuable piece of work, illustrated by photographs and drawings of sections, treating of the tympanic muscles and cavity in *Ornithorhynchus*, *Echidna*, *Mania*, cat, and mouse, *Archiv für Mikrosk. Anat.*, liii., 1898, 558.

33. The accompanying photographs show an example of bilateral chondro-epitrochlearis in the living subject. This was discovered by chance, the patient complaining of rheumatoid arthritis.

Along with this I have sent a photograph of a specimen of

the same anomaly from the dissecting-room at Leeds, which makes an excellent commentary on the living specimen.

T. WARDROP GRIFFITH.

34. SPECIMEN OF GREAT REDUNDANCY OF THE FOSSA OVALIS.—There were no cardiac symptoms or signs. The muscles and valves were normal, there were slight degeneration changes at the root of the aorta. On removal, the fossa was *gently* stuffed with cotton-wool, and the specimen hardened in formal.

The fossa ovalis is seen to be very deep, with well defined margins; dimensions $1\frac{1}{8}'' \times \frac{3}{4}''$. The valve itself was thick and substantial; a small perforation, about $\frac{1}{32}''$ in diameter, was present just above its middle (seen as a dot in the photographs). Viewed from the left auricle, the valve formed a great convexity projecting into that cavity; the actual bulging was, of course, caused by the stuffing. At its upper and anterior part, it was attached to the auricular wall by two strong processes, and above these by many small cords. Between the two strong processes was a crenated depression, leading to a small deficiency at the upper and anterior part of the fossa ovalis, which permitted the passage of a goose's quill. One or two smaller deficiencies existed between the smaller processes.

T. WARDROP GRIFFITH.

35. I have received from Professor Wardrop Griffith the accompanying photographs to illustrate his paper on an opening unconnected with the fossa ovalis, published in the last number of the *Journal*, p. 261. They should have been printed in connexion with his paper.

36. EPARTERIAL BRONCHIAL SYSTEM.—Professor Huntington has examined the arrangement of the branching of the bronchial tubes and reviewed in the *Annals of the New York Academy of Science* for May 17, 1898, the literature of the subject. He shows that there is a complete gradation in series from the symmetrical bilateral hyparterial type found in *Hystrix* to the complete symmetrical eparterial type in the seal. He regards the lobes of the human lungs as being related thus:—

Right side.	Left side.
Upper + middle lobe = upper lobe.	
Lower + cardiac lobe = lower lobe.	



1



2



3



4

DR GRIFFITH ON AN INTERAURICULAR OPENING.

[To face p. 502.]



37. THE SHAPES OF THE FŒTAL LUNGS.—Professor Huntington has given a careful and accurate description of these in the *Medical Report of the Society of the Lying-in Hospital of the City of New York*, 1897, and he has indicated the changes which take place in the early stages of development. The use of formalin has enabled him to make these observations, the results of which are represented in beautifully definite plates. But why *hilus*? There is no such word in Latin. *Hilum* is the classical word.

38. OBSTRUCTION OF THE INFERIOR VENA CAVA.—In the *Scalpel* for Jan. 1899 (iv. p. 13), Professor Wardrop Griffith describes two cases of obstruction of the inferior vena cava. In one, the cause of the occlusion was an aortic aneurism, but in the other there was no apparent reason for the condition. In this instance the blood ascended by the vena azygos, which had a large connexion with the right renal vein. The seat of the obstruction was opposite the lower border of the lobus Spigelii.

39. THE ARTERIES OF THE INTERVERTEBRAL GANGLION AND OF THE CENTRO-SPINAL NERVES IN MAN.—In the *Monthly International Journal of Anatomy*, xv. p. 353, Dr W. Tonkoff, of St Petersburg, has given a translation into German of his dissertation on this subject, published in Russian in February 1898. These observations are the result of the minute observation of 35 subjects. He has here recorded the vascular supplies of all the spinal ganglia, and also those of the brachial plexus and its branches, the lumbar plexus and the anterior crural nerve, and the sacral plexus and great sciatic nerve. He discusses at length the importance of these as collateral channels of circulation.

40. The following papers on the Thoracic Anatomy and the Vascular System are noteworthy:—

BARBIERI on the innervation of arteries and capillaries, *Journ. de l'Anat. et de la Physiologie*, xxxiv. 583.

GIBSON, a case of supernumerary mamma, *Glasgow Med. Journ.*, l. 37.

STOYANOV, cases of polymastia and polythelia, *Bull. Soc. d'Anthropologie*, Paris, ix. 301.

PROFÉ, ontogeny and phylogeny of the mammary organ, *Anat. Hefte*, Wiesbaden, xxxvi. 247.

WARDROP GRIFFITH, a case of fusiform dilatation of the œsophagus, *Med. Chronicle*, Nov. 1898. This example resembles the classical specimen figured by Luschka in *Virchow's Archiv*, xlii. pl. 11, fig. 1.

GANGITANO on an aortic opening, with two semilunar valves, *Clin. Med. Ital.*, xxxvii. p. 234.

SALVI on the arteria dorsalis pedis, *Atti d. Soc. Toscana di Sc. Nat.*, v. 12.

WYNKOOP on an anomaly of the arteries of the forearm, *New York Med. Record*, v. p. 879.

FRANKLIN P. MALL, development of the internal mammary and deep epigastric arteries in man, *Johns Hopkins Hosp. Bulletin*, No. 90-91, 1898.

HABERER, the veins of the testis and their varieties, *Archiv für Anat. und. Physiol.*, 1898, p. 413.

STAHR, the lymphatic glands of the submental and submaxillary region, *ibid.*, p. 444 (usually three in each set on each side).

MIURA, example of sinistral and post-œsophageal origin of right subclavian artery. Communication between the spermatic and splenic veins, *Mittheil. aus d. Med. Fakult.*, Tokio, iv. 1.

41. ABSENCE OF THE SPLEEN.—Through the kindness of Dr Hankin, of Agra, I have received a copy of the report of an autopsy made by Major G. H. Baker (I.M.S.), at Gorakhpur, last November, on a native woman aged 20, and well nourished, in whom there was not even a trace of a spleen present, "not even a rudimentary organ could be discovered after careful dissection." I do not know any comparable case.

42. The following papers on Abdominal Anatomy are noteworthy :—

HENDRICKSON on the musculature of the extra-hepatic biliary system, *Johns Hopkins Hosp. Bull.*, 1898.

MOSER, a liver with sixteen lobes, *N.Y. Med. Record*, liii. 671.

CASTELLANI on Brunner's glands, *Bibliograph. Anat.*, vi. 226.

ROND, an anomaly of the duodenum and transverse colon, *ibid.*, vi. 209.

STOPNITZKI on the anatomy of the human intestine, *Monthly International Journal of Anat.*, xv. 327. This paper is particularly interesting in connection with Prof. Robinson's paper, in this number of the *Journal*.

FRANKLIN P. MALL, development of the human intestine and its position in the adult, *Johns Hopkins Hosp. Bull.*, No. 91, 1898. A valuable addition to our knowledge of intestinal growth and position, including an analysis of the position of the intestine in forty-one bodies.

FRANKLIN P. MALL, the lobule of the spleen, *ibid.*, 1898. An attempt to isolate the organic units of which the spleen is built up.

KOHN on the suprarenal bodies, *Prager Med. Wochenschr.*, xxiii. 193.

RADZIEJEWSKY on the suprarenal bodies, *Berlin. Klin. Wochenschr.*, xxxv. 572.

VINCENT on the suprarenal bodies, *Monthly Internat. Journ. of Anat.*, xv. 305.

WIESSEL on supernumerary suprarenals, *Wiener Klin. Wochenschr.*, xi. 443.

FENWICK, clinical notes on the rectal contour and consistence of a thousand prostate glands, *Brit. Med. Jour.*, Feb. 18, 1899, p. 395.

SIEBOURG, a case of complete male pseudohermaphroditism (*Deutsche Med. Wochenschr.*, xxiv. 367).

SOREL and CHEROT, a case of pseudo-hermaphroditism, *Archives provinc. de Chirurgie*, i. p. 367.

ZAUFAL on bilateral defect of the kidneys, *Prager Med. Wochenschr.*, xxiii. 170.

KELLOCK on complete hypospadias with cleft scrotum, *Brit. Med. Jour.*, 1899.

SAALFELD on the glandulæ Tysoni, *Archiv f. Mikrosk. Anat.*, liii. 212.

TANDLER and DÖMÉNY on the glandulæ Tysoni (*Wiener Klin. Wochenschr.*, xi., No. 23).

MOYNIHAN on peritoneal fossæ, *Brit. Med. Jour.*, 1899, 522.

43. THE ANSA INFRAHYOIDEA.—Professor Huntington's dissections of the branches of the first, second, and third cervical nerves in the cynomorphous apes form valuable illustrations of the cervical nature of the group of nerves formerly called *descendens noni* and *communicantes*. It is, I suppose, too much to expect that the misleading genitive 'hypoglossi' should be superseded by a term which more accurately conveys the idea of the real relationship of these nerves, but the fact of their cervical nature should be more distinctly emphasised in anatomical descriptions; and Professor Huntington's figures and descriptions afford an instructive commentary on the human arrangement. They are published in the *Transactions of the New York Academy of Sciences* for March 3, 1897.

44. The following papers on the Nervous System are worthy of note:—

DUOESCHI on the central innervation of the external sphincter ani, *Riv. di Patol. Nerv. e. Ment.*, v., No. 6.

HOCHSTETTER on the development of the brain, *Bibliotheca Medica*, heft 2.

GRANFIELD on the physiological rôle of the anastomosis between the

superior and inferior laryngeal nerves, *Sitzungsab. d. k. Akad. d. Wiss.*, Berlin, 107, p. 7.

MONAKOW on the anatomy and physiology of the inferior parietal lobule, *Archiv f. Psychiatr. u. Nervenkrankheit*, xxxi. p. 1.

TOURNEUX and SOULIE on the early development of the pituitary body in man, *Comptes Rendus Soc. Biol.*, Paris, v., 1898, p. 896.

FLORENCE R. SABIN on the anatomical relation of the nuclei of reception of the cochlear and vestibular nerves, *Johns Hopkins Hosp. Bull.*, 81, 1897.

HOFMANN, fixation of the theca vertebralis in the vertebral canal, *Archiv f. Anat. u. Physiol.*, 1898, 403. Author describes anterior and dorso-lateral ligaments and cervico-interspinous ligament, as well as the individual sheaths of the nerves, as the means of fixation.

KLIMOFF on the fibres of the cerebellum, *Arch. für Anat. u. Phys.*, 1899, 11.

45. THE RECONSTRUCTION OF THE STATURE OF PREHISTORIC RACES.—Professor Karl Pearson's last "Mathematical Contribution to the Theory of Evolution" is upon this subject. It is not easy reading, but undoubtedly it is a paper of the first importance for physical anthropologists. I hope to be able to give, in a future number, a short abstract of the results of the whole series of Professor Pearson's interesting papers, so far as they are of interest to students of anatomy and anthropology.

46. The following papers on Physical Anthropology are of interest:—

HOLL, the construction of the face, *Mittheilung. d. Anthropol. Gesellsch. in Wien*. Two plates and numerous figures.

RANKE on the frontal process of the temporal bones in primates, *Sitzungsberichte d. Math. Phys. Cl. d. Akad. d. Wissensch. zu München*, xxviii., 1898.

DUBOIS on the relation of brain weight to body size in man, *Archiv für Anthropologie*, xxv. 423.

BLOCH, the anthropology of the lips, *Bull. Soc. Anthropol. Paris*, ix., 1898, p. 222.

PITARD, fifty-one French criminal crania, *ibid.*, p. 237.

VRAM on the lower human premolars, *Atti di Soc. Romana di Anthropol.*, v. 1.

SHRUBSALL, study of Abantu and Ashanti skulls, two papers in *Jour. Anthropol. Inst.*, 1898, p. 55.

HADDON, craniology of the Arawaks of Jamaica, *Journ. Inst. of Jamaica*, July 1897, ii., No. 4.

BARTH, account of 161 ancient Norwegian crania, *Christiania*, 1866. (The majority were dolichocephalic, orthognathous, leptoprosopic, and showed a tendency to synostosis.)

NINTH REPORT ON RECENT TERATOLOGICAL LITERATURE. By BERTRAM C. A. WINDLE, D.Sc., M.D., M.A.,
Professor of Anatomy in Mason University College, Birmingham.

[The author of this report will feel greatly obliged if writers on teratological subjects will supply him with reprints of their papers, for use in the preparation of future reports.]

I. EXPERIMENTAL.

FÉRÉ (i.) has experimented on the development of eggs into which *creatine* had been *injected* in small quantities. Such eggs developed more rapidly than the controls. In several series of experiments, 108 eggs of either kind were hatched; of these, 69·44 p.c. of those into which pure water had been injected developed, and 81·38 p.c. of those which had received creatine, and the latter were also further advanced in development. Further experiments with xanthocreatine had a similar result, 68·66 p.c. of the eggs with water developing, and 76·66 p.c. of those with xanthocreatine, and the latter were also further developed. MITROPHANOW (ii.) tried the experiment of *varnishing* one side of the egg of the fowl before incubation. No special results were obtained so long as the process was conducted at the ordinary temperature, but when this was increased, at the end of ten hours it was found that the area pellucida had an irregular outline approximating to the circular, and that the primitive groove had developed only at its anterior end. At the end of fifteen hours or more the primitive groove was clearly formed, though better marked at its anterior end, its posterior extremity not reaching the edge of the area pellucida, and being also bent to one side. These characters were very constant.

KÆSTNER (iii.) obtained a number of malformations, including hydrops, omphalocephaly, arrested medullary folds, vascular areas without embryos and unconnected with the embryo, by the process of *interrupting the incubation* at an early period for a relatively long time, the eggs during this period being kept in a room at a temperature between 18° and 24° C. The interruption, which varied in length, was as much as sixteen days after six hours of incubation. SCHAPER (iv.) has made some very instructive *experiments upon young tadpoles*, 5-6 mm. in length, from which he cut off, with a very sharp lancet, a dorso-frontal segment of the head, which contained usually the entire brain, with the medulla oblongata, the anlagen of the eyes, the olfactory and auditory organs. The vegetative part of the head, especially the mouth cavity and the sucking disks, were always preserved. The embryos in certain cases recovered from the shock of the operation and swam about, their development continuing. Subsequent examination by serial sections showed that the head was en-

tirely brainless, without eyes, smelling and hearing organs. Nowhere was a trace of regeneration of these organs to be encountered. The healing of the operation wound was brought about by a proliferation of the mesenchymal tissue, which was superficially covered by a layer of ectodermal epithelium. At the posterior end of the medulla was an irregular accumulation of cells, which were proved to belong to the neural tube by their continuity with it posteriorly. In the dorsal region, a spinal cord in its morphological outlines was visible, but higher magnification showed that its cellular constituents were in a state of extreme degeneration, and that, therefore, any specific functional activity of the spinal cord was out of the question. These facts showed that the larva lived, moved, and developed during seven days without brain and medulla, and during the second half of its life, even without a functional spinal cord, or, in other words, that the experiment was successful in producing not only a living anencephalic, but at the same time an amyelic frog larva. The absence of the central nervous system was therefore of practically no demonstrable importance whatever in the differentiation of the embryo, at least during the period of the experiment. All the organs of the operated larva, except those the elements of which were directly removed by the operation, had not only developed in typical shape and correlative arrangement, but had also undergone a typical histogenetic differentiation. Thus it is clear that the central nervous system has, during a certain early period of development, no functional influence whatever upon the vital processes within the developing organism: it neither receives specific centripetal stimuli, nor sends any specific stimuli to the periphery; that is, it has neither sensory nor motor nor morphogenetic functions. In the same way, the metabolism is independent of it, for the larva grew simultaneously with progressive resorption and assimilation of the yolk. All stimuli, therefore, outer as well as inner, must have met the individual cells *directly* during this period, without transmission by means of a conducting nervous system. This development must have taken place according to the so-called "*principle of auto-differentiation*"; which means that the power of development in a definite direction, and into a definite end product, is from a very early period potentially inherent in the smallest parts of the germ. A correlative development of neighbouring organs, or a functional control of the development of the entire organism by a central organ, is nowhere to be proved. It is therefore as a kind of "*mosaic work*" that the animal body is built up. A recent theory of Roux seems to offer an explanation of certain teratological monstrosities, such as anencephaly and amyely, in which, in spite of the absence of the central nervous system, the rest of the body has developed perfectly. Roux divides the development of every organism into an early period of what he calls "*organogenetic development*," and a later period of "*functional development*." During the first period, the different organs develop by means of an inherent endogenous energy in a definite direction, without influence from outer stimuli, that is, by auto-differentiation; during the second period, however, the gradually developed specific function of the individual

organ, as well as the co-operative function of all the organs of the body, are the main stimuli for further growth and development, and are indispensable for the normal life of the single organs, as well as of the entire organism. From this, it would appear that the first stage in the case of the human embryo must last until very near the normal period of gestation. In the second paper, the same author deals more at length with his observations, and particularly narrates one in which the anlage of one of the eyes had been left completely severed from all nervous connections. Its development, nevertheless, proceeded, and at the period that it was examined was but little inferior to that of the eye of a normal embryo. It had thus developed quite independently, but without obvious deviation from its normal course, a fact which the writer thinks throws a light upon the independent development of detached and isolated organs in dermoid tumours and teratomata.

BARFURTH (v.), dealing with the subject of *Cauda Bifida*, distinguishes between an *asyntaxia caudalis* corresponding with the *asyntaxia medullaris* of Roux, cases of which have been described by O. Hertwig, and true *cauda bifida* and *trifida*, which, as is well known, may occur in lizards after the tail has been broken off. Bifurcation of the tail with the medullary canal, chorda, and segmental musculature was produced by the author by two methods in embryos of *Rana fusca* and other amphibians: (1) By cleaving the tail and using measures to prevent the union of the parts, a procedure which the tendency to union rendered not very satisfactory. (2) A more successful way was to pierce the middle piece of the tail in one or two places with a hot blunt needle, and then amputate the loose hanging piece of tail behind the distal point of puncture. FÉRE and ELIAS (vi.) give a further account of the results obtained by *grafting portions of embryos* under the skin of adult fowls. (An account of previous experiments will be found in last year's report.) Eyes from chicks incubated for eight days were grafted under the skin of fowls, generally in the pectoral region. Sometimes several eyes were inserted together, and when this was the case they generally grouped themselves together, so as to look like a miniature bunch of grapes under the skin. They may increase to a considerable size; in fact, in one case eighteen months after the grafting, the individual eyes were 7-8 mm. in diameter, the average size of the grafted eye being 3 mm. The pigment disappears gradually after a few weeks. When the tumours were removed, they were found to consist of cysts filled with a viscous fluid, and hyaline cartilage was also found. Other parts of an embryo will also grow when grafted, and in one of these a fragment of bone was found to have developed.

II. GENERAL

It is with great regret that the writer chronicles the last paper of Professor GIACOMINI, who has done so much to enlarge our knowledge of the *early pathology of the embryo*, and whose communications on

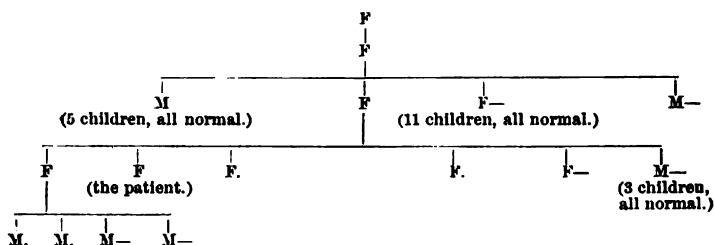
this subject have formed a part of all or nearly all of these reports. The eleventh communication (vi.) deals with a case in which, when the chorion was opened, two vesicles were seen, one of which appears to have been an empty amniotic sac, the other the yolk-sac. The former bore at one point a small mulberry-like body, which on microscopic examination proved to consist of several small lobes containing small cavities. The lobes were formed of small round cells, staining very brightly, which resembled the mesoderm cells of much degenerated embryos. They were covered by a single layer of cells in many places, which at some points assumed the appearance of epithelial cells. He does not think that this represented the embryo, but the altered stalk of the yolk-sac, which in the absence of the embryo had developed into a wholly atypical structure. The cavity of the amnion was quite empty, and showed no signs of an embryo. LACHI (viii.) describes another case of *early mal-development of the embryo* in which the yolk-sac was almost totally included within the amniotic cavity. The embryo was much arrested in development, especially in the cephalic region, the mesoblastic somites were absent, and the lateral mesoblast undivided except in a very small tract. The author thinks that all the circumstances of the case point to some disturbance which has retarded the development of the mesoblast. K. and G. PÉTRÉN (ix.) have contributed a lengthy memoir on a subject now claiming much attention, namely, the *condition of the nervous system in anencephaly and amyely*. The memoir, which contains copious references to the literature of the subject, is too long for abstraction in this report, but is deserving of the study of all working at this point. SMITH (x.) describes a case of *multiple canals in the spinal cord* of a chick embryo of ten days' incubation. It was incubated under ordinary conditions, and was quite normal save for that portion of the cord extending backwards from the region of the anterior limbs. Beyond this point it showed for some distance a second central canal, and still lower, a third and a fourth. Then these accessory canals were lost, and three fresh canals were seen, all very short, and soon lost in a series of sections, showing that they must have been nearly spherical. Then a new secondary canal appeared, which was the largest of all, nearly equalling in size the proper canal. This was also the most persistent of all. Further, canals appeared at more posterior levels, and one of these was contained in an outgrowth from the cord, which reached the dorsal surface of the body and lay in a small depression formed in the epidermis. None of these canals opened into one another nor into the true central canal, and all were lined with the same kind of cells as those which lined the latter. The author thinks they must have arisen as outgrowths from the central canal, though in what manner is not clear. All the other embryos from the same batch of eggs were normal, so that external conditions do not appear to have given rise to the condition. GUDDEN (xi.) describes a case of a human embryo in which there was a remarkable *swelling of the inferior vermiform process of the cerebellum*, which projected into the fourth ventricle, and the spinal cord at the point of transition from

the medulla was bent upon itself. There was a spina bifida in the lower dorsal region, and here also there was a separation of the cord into two parts, the condition of which is fully described in the paper. THEODOR (xii.) describes a somewhat similar case, in which in a *spina bifida* the cord was double from the third dorsal vertebra backwards. A microscopic examination of 1650 sections of the two cords shows that the process occurred as follows: A wedge of grey and white matter pushed its way into the cord posteriorly, and so spread out the posterior columns. This process proceeding, the central canal was divided into two parts, each smaller than the original single canal, but with an epithelial lining. The anterior septum also grew in size, and the result was a complete halving of the cord. The central canal gave off several branches, so that a canal system was formed throughout the entire cord. FRIEDMANN (xiii.) describes a case of *meningo-myelocele* situated near the sacrum, the tumour being about the size of an apple and full of fluid. The anus was situated at the hinder border of the scrotum and to the left side. There was also ectopia vesicæ, with separation of the pubic bones, right cryptorchismus, and an unusually long processus vermiformis. FUSSELL (xiv.) describes an *otocephalic monster*, in which the body was normal, the head had no eyes, but a median slit $\frac{3}{8}$ inch long on what would correspond to the forehead. There was no trace of a nose. One inch below the orbit was the opening of the mouth, with normal lips. On the right, on the level of the mouth, was a malformed ear, and $\frac{1}{2}$ inch to the right of the mouth the auditory canal ended in a cul-de-sac. Between the ear and the mouth was a fleshy prominence. On the top of the head was a heart-shaped sac, containing fluid, and measuring $6\frac{1}{2}$ inches in its longest diameter. The bones of the vault of the skull were absent, and so were the tongue and upper and lower jaws. There was no opening between the mouth and the upper part of the pharynx. The brain was rudimentary in structure.

HÜBL (xv.) describes a case of *cyclops* in which the eyes, as such, were absent, but in the centre of the face was a projecting prominence on which were two irides and pupils. Above this was a snout-like tube. There was also hydrocephalus, umbilical hernia, atresia ani, talipes, supernumerary digits, persistent foramen ovale, double atresia of the ureters, and hydronephrosis. RABAUD (xvi.) contributes an important memoir on the condition known as *omphalocephaly*. These curious forms were thus described by Dareste, who first called attention to them. In these monsters the head seems to emerge from the umbilical opening, and the heart, sometimes single, sometimes double, is to be seen in the neck or dorsal region of the embryo, exactly, if the comparison may be allowed, like a sack on the back of a porter. The author, from a careful examination of chick-embryos thus affected, concludes that the nervous system plunges towards the endoderm and envelops itself in it, making a long hernia below the plane of the embryo. This nervous head, clad with endodermic epithelium, is secondarily surrounded by the alimentary canal, which closes completely upon it. The principal vessels and the notochord follow the nervous system, on account of their endodermic origin.

These vessels are united to the heart by collateral branches. The mechanism of the malformation must be attributed to an inversion at the moment of the appearance of the nervous and cardiac systems. VIRCHOW (xvii.), dealing with the question of *Phocomelia*, considers that it differs from foetal rickets in the absence of the sternal rosary and in the general condition of the bones. It is, he thinks, more closely allied with congenital cretinism, but he thinks that such cases should be placed in a category with hemimelia and peromelia, as a series of defects which, commencing with simple hypoplasia of the extremities, ends in complete teratological defects, tending towards the condition of the acephalous twin. MAYGRIER (xviii.) describes a case of *achondroplasia*. The foetus was the offspring of a healthy mother and a somewhat rickety and alcoholic father. The limbs of the foetus were short and curved, whilst the dimensions of the trunk were fairly normal. There was hydrocephalus, and the placenta was covered on its uterine surface with numerous calcareous grains, a fact which the author thinks may be correlated with the changes in the bones of the foetus. ARNHEIM (xix.) gives an account of a child *æt.* 3 weeks, in which there was *unilateral hypertrophy* of all parts on the right side. FÉRE (xx.) finds that in *infantile hemiplegia* there is considerable facial asymmetry, the affected side being smaller and the ear having a flattened helix and better developed Darwin tubercle, as well as being larger. As it is clear that in these cases the effects are due to arrest of development consequent upon the hemiplegia, the author thinks that a similar condition co-existing with mental weakness should not necessarily be looked upon as atavistic. PORIER (xxi.) describes the condition in a child of 15 days affected with *paralysis* of the right arm. On the outer side, where the musculo-spiral nerve turns round the humerus, was a depression in the skin, fairly deep, and lined with thickened skin, which the author thinks must have been caused by the pressure of an amniotic band. On microscopic examination it was found that all the elements of the skin were present and thickened, being nearly the thickness of that of the adult. The muscular fibres of the subjacent muscles were surrounded by more connective tissue than usual, and the fibres were smaller than normal, and their striation less clear. The fibrous tissue surrounding the fibrils of the nerves was thickened, and the fibres themselves altered, no axial cylinder nor nuclei being observable. In some fibres, thinned fragments of myelinel were present, in others it was quite absent. The author thinks that this was a case of peripheral paralysis caused by the compression of the nerve, and followed by trophic disturbances. MORESTIN (xxii.) describes a *number of abnormalities* co-existing in the same foetus. The left lower extremity terminates at the ankle, looking as if it had been amputated. This was not the case, for there was no fibula nor any signs of muscles in the leg. The right lower had three toes only, and the condition of the leg was as in the other. There was no anus nor external genitalia. The right lung was represented by a mass the size of a pea attached to the bronchus, and the left showed no division into lobes. There was transposition of the heart, with

perforate septum ventriculorum and a dextral aortic arch. There were two superior venæ cavæ, the stomach was small, and did not communicate with the small intestine. HILFA (xxiii.) describes the case of a boy who had a deformed head, pigeon-breast, contracted fingers on both hands, and a luxation outwards of both patellæ. One foot was clubbed and the other flat. It was noted at the time of birth that there was a very *small amount of amniotic fluid*, to which the author is inclined to look for the cause of the malformations. PENDRED (xxiv.) describes a case of *hereditary keratosis* or tylosis palmæ, which had been in a family for 150 years in unbroken succession. The family tree will exhibit the history, those not affected being marked thus —. It will be seen that the disease was transmitted mostly through the female side :



III. DUPLICITY.

MAYGRIER (xxv.) describes a case of *twin pregnancy* in the human subject, in which there was one placenta, one chorion, and two amniotic cavities. The cords were at a considerable distance from one another, and one had a velamentous insertion. There was hydramnios of one ovum. The fœtuses were of the same sex, but one was much smaller than the other. The larger had a hypertrophied liver and heart. The author inquires whether the differences in size between fœtuses of this kind are due to asymmetry of the vascular arrangements, causing one fœtus to receive less blood (Schatz), or to the fact that one has received less vitellus in the process of division. (The solution of the question may perhaps be found in the fact that there has been an unequal division of the ovum, of the kind produced by Driesch in the ova of certain invertebrates by shaking.)

ASSHETON (xxvi.) describes a very interesting *blastodermic vesicle* of a sheep, in which there were two perfectly separate germinal areas, each apparently perfect and capable of developing into a complete embryo. There was no evidence that this was formed by the fusion of two ova. The author thinks that it is just possible that in animals such as the sheep or pig, where more than one segmentation cavity may appear amongst the cells of the morula, an irregular splitting of the mass may lead to the formation of two embryos. LAGUNSEN and BUE (xxvii.) give a very full account of a monster with two heads and one body (*derodyme*), measuring only 19 mm. in length, and thus

being the smallest of the kind ever described. It was fortunately obtained almost immediately after delivery, and was hardened and cut into sections. The point of bifurcation externally was immediately below the ears. There were two vertebral columns, thus arranged: From a single but large sacrum, which presented some traces of duplicity, there projected backwards two distinct coccyges, and forwards two lumbar columns, still largely united. Beyond these were two cervico-dorsal columns, absolutely distinct from one another, and only connected by the medium of the ribs, each column bearing a head. There is a full discussion of the anatomy of the monster, and a consideration of the causation of double monstrosity, the authors accepting Duval's view that it is due to polyspermia. As regards the history of the case, they think that there were first two primitive lines close to one another, and slightly curved, with their convexities directed towards one another, as in Allen Thomson's case, or perhaps, less probably, a single thick primitive line, really double, and more or less clearly bifid anteriorly, as in the cases of Gerlach and Hoffman. At the extremities of these two lines were developed two distinct cephalic prolongations, two neural canals, and two notochords. Up to this point it would have been possible to have had a pair of twins from this condition had the two primitive lines been sufficiently distant from one another. But so close were they that there was between them posteriorly only a narrow territory of common blastoderm, so that in the sacral region, though there were two cords, there was only a single cartilaginous vertebral column. From this point there was a process of gradual fusion of adjacent viscera, so that the posterior extremities and genitalia and termination of the abdominal viscera appear as if they belonged to a single individual. BARBOUR (xxviii.) gives a very interesting account of the *double-headed specimen of Chrysemys picta*, which he had originally described in the *American Journal of Science*, vol. xxxvi. In this tortoise, the carapace, which was somewhat broader than long, and slightly distorted, bore the customary legs and tail, but there were two perfectly developed heads and necks. The account of the character of the two individuals is of great interest:—"There were two dispositions; the one quicker, more timid, and more irascible, the other stolid. Each head could hear, see, eat, drink, and breathe independently. Though afterwards acquired, there was originally no concerted action between the right side and the left. However, with surprising frequency, the two did act in unison, and simultaneously, as if there were correlation by a common nervous system. They might, or they might not, each drink, sleep, or swim, as each willed. When one side, with its organs and appendages, slept, or was inert, the other, with this deadweight as a centre, could but describe a circle—a course which it found endless. Here there arose a beautiful example of adaptability. It learned to drag itself sideways wherever it would—over the whole yard. This was the right half (never the left), which had a timid, quick, and irascible temperament. They swam well together, but walked together awkwardly. As they walked the fore-legs acted simultaneously, so in turn the hind-legs, leaving alternately the front and back of the

shell without support. Thus by a slow rocking gait they could go where they would. In starting, they almost invariably pulled persistently in opposite directions, which drew them laboriously backward three or four feet. Resting a moment, they would start together, as above described, and make the circuit of the yard." BROOM (xxix.) describes the anatomy of a *four-winged chick*. It had two vertebral columns placed right and left, a single head, and two tails, well apart from one another, each with a normally developed pelvis. The œsophagus, gizzard, liver, and spleen were single, and the alimentary canal bifurcated two inches below the gizzard. The wings were very curiously placed, consisting of an anterior pair, apparently normally placed with respect to the head, and a posterior pair situated close together in a cleft between the two diverging axes, with the elbows pointing outwards and the phalanges directed away from the head. A careful examination of the muscles and nerves showed that of the anterior pair the right belongs to the right spine as its right wing, and the left to the left as its left. Of the posterior, the right belongs to the right spine as its left wing, and the left to the left as its right. A curious case of *posterior dichotomy* has been described anonymously, and figured in the *British Medical Journal* (xxx.), the subject being a boy aged 12 years. The femur of the supernumerary limb moves freely in an apparently perfect joint, situated in the sacral region of the pelvis. The leg is somewhat atrophied. Close to the knee-joint is a conspicuous tapering appendage, with a bony core. It possibly represents the other (left) leg of the abnormal pair. The whole supernumerary limb can be moved freely by its bearer, who cannot, however, use it in walking, as it is a little shorter than the normal pair. He can sit on the right femur, with the knee touching the ground. He walks but little inconvenienced by his third limb, which he keeps bent against his back. The boy himself is a well-formed male. Between his back and the attachment of the abnormal limb projects a kind of labium, with a voluminous clitoris or malformed penis protruding at the upper angle. These, of course, represent an imperfect penis and scrotum. From under the labium, a tumour, having the size of a small orange, bulges rather prominently. Its rose-coloured surface resembles a mucous membrane, and is always moist, having the appearance of an everted bladder. The rectum of the boy opens close by, but it has no sphincter. A case somewhat resembling this is described by SHAWER (xxxi.), where the autosite was a girl, and had attached an *acephalous monster* by a broad base to the region extending from the pubes to the sacrum, the nates being obliterated. The author states that the parasite possessed a penis and testes, but it was evidently not carefully examined, and this is clearly a mistake, the organs in question being no doubt a clitoris and prolapsed ovaries. SCHATZ (xxxii.) gives a long and valuable account of *Acardii*, which he thus classifies with respect to their origin:—(1) *A. completi* (event. mono-, abrachii and mono-, apus), which possess a head and body, corresponding to a nearly sufficient nourishment through wide placental anastomoses. (2) *A. acormi*, which possess only the head and at most traces of trunk and extremities; corre-

sponding to insufficient nourishment of the acardiacus through too small blood-supply on account of venous outflow from the head, usually through the persistent communicating yolk-veins, often through the superior vena cava and true umbilical vein, whilst the inferior vena cava is atrophied, or through a supplementary umbilical vein which comes from the jugular, and has a subcutaneous course, the inferior vena cava being atrophied. (3) *A. acephali* (bi-, mono-brachii and bi-, mono-, apodes), which possess the pelvic end of the body as their chief portion, to which may be attached other parts of the body, but not the head; corresponding to insufficient nourishment of the Acardiacus through inadequate blood-supply, owing to venous outflow from the pelvic, and usually through Burow's supplementary umbilical vein, often through the true umbilical vein, or through several supplementary umbilical veins coming from below. (4) *A. amorphi* (globuli), which, more or less clearly, possess all the rudiments of the embryo in the shape of a roundish bag of skin from which head and extremities project only as traces, corresponding to very early narrowing of the allantoic veins, the oedema being due to the insufficient calibre of the same vessel. KÆSTNER (xxxiii.) gives an account of two early *double chick embryos*. (1) Had a double notochord, and anteriorly showed on section the abnormally broad and dorso-ventrally compressed medullary tube lying open in the cephalic region. Further back, in the region of the closed medullary tube, the two chordæ appeared, and still further back, in the region of the mesoblastic somites, they lay below the medullary canal, separated from one another by a third azygos primitive segment. The two normal segments lay one on either side of the cord. Near the hinder end and in the region of the unsegmented mesoblast, the two cords enlarge, approach one another and fuse, the third somite being replaced by a small rod lying ventrally to the united cordæ. (2) A specimen of posterior duplicity of 48 hours' incubation. Both parts were equally developed, and were separated as high as the region of the mid-brain, only the fore-brain being common to the two. There were four otic vesicles. STOSS (xxiv.) gives a review of the question of *duplicity*, and the various theories which have been put forward to account for it, with illustrative cases drawn from amongst malformations of domestic animals.

IV. HEAD AND NECK.

PFLÜGER and PILCZ (xxxv.) deal with the subject of *microcephaly* in a lengthy and fully illustrated paper, containing accounts of cases. They conclude that it is due to a disturbance in the growth of the brain or skull, though which is the primary cannot be absolutely settled. However, the extraordinarily varied and serious abnormalities of the brain, when compared with the often not specially remarkable changes in the skull, seem to indicate that the primitive change is due to some unknown disturbance in the development of the brain, and that the alterations in the skull are secondary. The diminution in

size of the skull stands in most cases in no proportion to the smallness of the brain, *i.e.*, the micrencephaly is in most cases of a higher grade than the microcephaly which co-exists with it. The authors venture the suggestion that possibly microcephaly is preceded by a foetal periencephalitis which induces a hydrocephalus externus, which primitively arrests the brain in its development, whilst permitting the skull to grow, and that the latter, after the absorption of the fluid, either is likewise arrested in its growth, or directly, but still during intrauterine life, diminishes. The authors also point out that in the greater number of cases the sutures are not united; even the frontal suture may persist.

FREY (xxxvi.) gives an account of a family in which there were several *microcephalous children*. The mother gave birth to (1) a normal male, (2) a microcephalous boy, (3) triplets, *viz.* a normal boy and microcephalous boy and girl, (4) a microcephalous girl, (5 and 6) two normal children. The head measurements of three of these, at the ages of 42, 45, and 49 respectively, are given. BIRKNER (xxxvii.), in a paper on the *so-called* 'Aztecs,' which are really mulattoes, and have been exhibited at various times since 1851, and are now probably 50 and 55 years respectively. The author concludes that the growth of the human cranium becomes less and less rapid in the course of development. From birth up to the second year the length of the skull increases to the same extent absolutely, as it does from the second to the third year, and from the fifth to the adult age. The breadth of the cranium increases from birth to the age of two years as much as it does from the latter age to adult life. The same is true as to the horizontal curve. Considered from the point of view of these three measurements, the 'Aztecs' correspond to children of two years of age. But from the point of view of the increase in size since the period of the second dentition up to the adult period, as judged by measurements taken at various times, they do not fall behind normal individuals. The increase in length, breadth, and horizontal curve do not fall below the mean increase in a healthy man. The arrest of development must therefore have taken place before the epoch of the second dentition, and probably before birth. FRANCK (xxxviii.) describes a complete *fissure of the palate*, with absence of inter-maxillary bones and vomer. OSTERTAG (xxxix.) also described a similar *fissure* in a full-grown pig. The cleft was at the anterior part of the palate, and measured 8.0×2.5 cm., and did not extend through the alveolar border nor through the hinder part of the palate. LEOPOLD (xl.) calls attention to observations made on the *abnormalities of the uvula* by Dana and Hennessy (*New York Med. Journ.*, May 16, 1896), and adds observations of his own made upon 1686 soldiers. The chief irregularities, excluding the fission accompanying cleft palate, are—

	Leopold. Dana and Hennessy.	
Absence of the uvula, . . .	1	0
Supernumerary uvula, . . .	0	1
Uvula bifida, . . .	38	3

The size varies very much; normally it may measure from .75 cm.

in the child at the age of 14 to 1.5 cm. in the adult. The highest abnormal measurements were, from the former 2.0 cm. and for the latter 3.0 cm.

MORESTIN (xli.) described a *congenital tumour* removed from the lip of a child aet. 10, situated on the inner side, and projecting into the mouth. On microscopic examination it proved to be an angio-lymphoma.

A further example of *congenital tumour* is recorded by ROBIN (xlii.). It lay in the sterno-mastoid of a child aet. 15 days, and consisted of fibrous tissue invading and stiffening the muscular fibres, the interior part being almost entirely fibrous. There was no history of syphilis. KIRK (xliii.) narrates a case of *dental anomaly*, in which, projecting from the labial face of the alveolar border, and between its free margin and the nasal floor, was an irregularly formed mass of tooth-structure, showing enamel and cementum. Around this was a group of 13 additional supernumerary teeth, of the usual conical form. Another case of supernumerary tooth described is that of a single multituberculate tooth, lying within the arch and behind the central incisors of the upper jaw. HARRELL and JOACHIM (xliv.) each describe a case of a *canine tooth* embedded in the floor of the nostril. DORSEY (xlv.) notes the *absence* of both lateral *incisors* in a Peruvian skull. BRADLEY (xvi.) describes the condition met with in two young pigs, both belonging to the same litter. Each had two *cerebral hernia* in the frontal region, and both had also a cleft of the soft palate. The chief points of interest in connection with these cases are, (a) the absence of the optic nerves, the corpora quadrigemina being normally developed, and the rudimentary character of the eyes; (b) the absence of the 1st, 3rd, and 4th cranial nerves; (c) the orifices of the hernia were through the centres of either frontal bone, and the two sacs were separated from one another by a bar of bone representing the contiguous parts of the bones and the frontal suture. BACKMANN (xlvii.) describes an *auricular appendage* on the right side of the neck in a man of 47, corresponding to the outer border of the sterno-mastoid. It possessed a nodule of cartilage in the centre. The paper contains a useful list of cases of a similar character.

V. THORAX.

BURCKHARD (xlviii.) has a paper on Embryonic *polymastia* and *polythelia*, which he sums up as follows:—(1) Amongst the embryos of pigs the occurrence of accessory or anal teats in both sexes is very frequent when compared with the condition in adult animals, about 37.62 p.c. of those examined in the course of his observations. (2) Anal teats were never found in front of the first normal pair, which are well characterised by their constant position. (3) On the contrary, anal teats were intercalated on one or both sides, between the normal two pairs of teats; or (4) as many as two pairs may be serially arranged behind the last well-formed pair, and may in the male stretch to the neck of the scrotum. (5) The linear arrangement

of all the teats, though it is slightly medianly inclined, makes it probable that they arise from a milk-fold, of which perhaps only the inguinal segment is present in the pig. (6) Deviations inwards of teats from the linear arrangement may be due to irregular growth of the skin, caused by the absence of the corresponding teats of the opposite side. (7) The mammary organ of the pig of to-day is undergoing a reduction in a caudo-cranial direction. (8) As in the case of the human subject, the anatomical structure of anal teats has to be divided into (a) polymastia, with all the attributes of a normal but very small breast, a 'mikromamma' and a 'mikrothele.' Functional and non-functional polymastia are to be distinguished, in these small milk-organs, when they persist exceptionally in pigs of either sex. (b) Pseudo-teats, or polythelia, which consist of imperforate wedges of skin, with more or less distinct elements of a breast, such as smooth muscular fibres, etc. (9) The pseudo-teats and most of the micromammæ atrophy after birth in lowland pigs, since amongst adult animals of this breed, as a rule, only four breasts are to be found. (10) The stretching of the skin, owing to the swelling of the functional udders, may be a part cause of the disappearance of the others. (11) All micromammæ and pseudo-teats must be looked upon as abortive, and not as progressive formations.

COCHÉZ and CRÉSPIN (xlix.) give some facts in connection with the subject of *congenital mitral stenosis* of a hereditary nature. APERT (l.) describes the case of a man æt. 35, in whom the right kidney was displaced into the pelvis and the *right lung* was divided into *four lobes*, the normally Y-shaped fissure having the shape of an X. There were superior and inferior (largest) lobes, and a mesial and lateral (smallest) intervening between them. SCHAFFNER (li.) has a contribution on the *lobus inferior accessorius* of the human lung, in which he states (a) that this lobe is a tolerably constant structure in both lungs, occurring in nearly 50 p.c. of all cases; (b) on the right side it is connected constantly with the cardiac bronchus alone, and is therefore exactly homologous with the cardiac lobe of animals; (c) on the left side it is connected with the inner branch of the second ventral bronchus; (d) the cardiac bronchus is an independent lateral bronchus, only occurring on the right side. COUSIN (lii.) describes three cases of *anomalies* connected with the *thoracic duct*: (a) the duct divided after passing to the left, and opened into the lower (posterior) border of the left vena innominata, 2 cm. internal to the union of the subclavian and jugular; (b) an extremely tortuous duct, which opened into the posterior aspect of the internal jugular at its union with the subclavian, but without forming a loop above it; (c) the duct divided at the 7th dorsal vert. into five canals, the two lateral being the largest. At the point of division was a small sac, from which the three smaller were given off. These united to form a single trunk, which joined the right lateral. At the 4th d. v. all united, and again divided into two behind the subclavian artery, of which one terminated in the usual position, the other entered the left subclavian vein 1.5 cm. external to this spot.

VI. ABDOMEN.

KEIM, ROSENTHAL, and HUGUIER (liii.) describe a case of *congenital diaphragmatic hernia*, which was found in a woman who died in the fifth month of pregnancy. The stomach and most of the intestinal coils were in the left pleural cavity, the heart lay on the right side, and the left lung was rudimentary. RISCHPLER (liv.) gives an account of three cases of *eventration* (ectopia abdominalis), which the author says is caused, as well as the concomitant spinal curvature, by abnormally extensive union between the amnion and the chorion. These deviations and unions must have occurred at a very early embryonic period, before the appearance of the liver and the establishment of its circulation.

ULMANN and DE ST BLAISE describe (lv.) a case of complete *atresia of the alimentary canal* at the level of the ductus omphalo-mesentericus. DIENST (lvi.) describes a case of *atresia ani urethralis*, with congenital hypertrophy and dilatation of the urinary bladder, bilateral dilatation of the ureters and hydronephrosis, persistent uterus masculinus and talipes in a female child æt 3 days. There is a full account of the literature of the subject.

MARTIN (lvii.) describes a case of what he believes to have been a *pedunculated accessory lobe of the liver*, weighing $3\frac{3}{4}$ lbs., which after remaining inert for years, had become the seat of degenerative changes and interstitial hæmorrhages. There was no continuity with the main gland, and it had apparently no ducts. Another case of *accessory lobe* is contributed by CHAILLOUS (lviii.). The lobe was pyriform in shape, and attached at the level of the quadrate lobe on the right side of the falciform ligament. HAUSER (lix.) narrates a case of *horseshoe kidney*, with the concavity upwards. On the right it received two arteries from the aorta and three on the left from the same source. There was also a further branch of unknown origin, which supplied both sides. Both pelves were symmetrically and probably congenitally dilated.

v. KARLTREU (lx.) describes a case in which, in a female, *both kidneys were united* with one another, and lay on the left side of the body. MONTGOMERY (lxi.) recounts an instance of *abdominal teratoma* which had become malignant in a girl æt 12. It lay on the right side of the abdomen and within the peritoneal cavity, attached to the ascending colon, and weighed 2 lbs., its surface was mostly of skin, and internally it had cysts, with pieces of bone and cartilage, ciliated epithelium, nervous elements, and even a tract of retinal pigment epithelium. The author gives an account of other teratomata which have become malignant. The most remarkable of these is a case of ordinary congenital sacral tumour in a patient aged 55, which became malignant after frequent injuries. After removal it recurred, and epithelial cancer occurred in the inguinal glands.

VII. GENITALIA.

L VETT and COUNCILMAN (lxii.) describe a case of *scrotal teratoma* in an infant æt. 3 weeks, which contained striped muscular fibres, hyaline cartilage, and newly formed bone, also structures resembling those of the eye. What makes the case remarkable and even unique was that after the death of the child, some months later, a tumour of a similar character was found between the dura mater and skull, a second teratoma which had caused the death of the child, and which contained structures derived from all three of the germinal layers. WRAIT (lxiii.) describes a case of *double congenital hernie of both Fallopian tubes* into the canals of Nuck in an infant æt. 2½ months.

NEUGEBAUER and WITTHAUER (lxiv.) give an account of a number of cases of *hermaphroditism*, chiefly of medico-legal interest, of which a full summary will be found in the abstract p. 78 in the *Brit. Med. Jour.*, 1898. The most interesting of these from the anatomical point of view is one recorded by Strobe in *Ziegler's Beit. z. Path. Anat.*, xxii., 1898. It is that of a male who died at the age of 63. He had been married, but nothing could be learnt as to his sexual powers. The external form was masculine, with a scanty beard. The penis and urinary meatus were normal, the former measuring 4 in. after death. The scrotum was empty. On opening the peritoneal cavity a well formed uterus was discovered, its fundus 2½ in. broad. The Fallopian tubes and round and broad ligaments were all present. Each Fallopian tube was related to a testis and epididymis, and neither was fimbriated. The uterine cavity opened into the caput gallinaginis of a well formed prostate; on each side was the orifice of a well-formed Wolffian duct. The urethra was normal. Microscopical examination showed that the two glands were testes; their development had been arrested, and the uterus masculinus had become abnormally developed. (This case may be compared with one by Jacques, in the sixth of these reports, No. xlv.) CARSON and HRDLICKA (lxv.) describe a case of *pseudo-hermaphroditismus masculinus*. The subject possessed female characteristics in mind and body, had a rudimentary penis with hypospadias, and without a meatus, and a feminine urethra. Both testicles were in their proper places on either side of the widely cleft scrotum, the opposed halves of which were clad with mucous membrane. There was a fairly well-formed hymen and a vagina, with probably very rudimentary female internal sex organs.

NEHRKORN (lxvi.) describes a *persistence of the sinus uro-genitalis*. The child, æt. 11 months, suffered from pyometra, and had hydro-nephrosis with dilated ureters. There was an apparent absence of vagina. The uterus was connected by a narrow canal with the bladder, where it opened between the orifices of the ureters. The passage from the bladder outwards opened into a narrow epidermis-clad cleft, the vestibulum, bounded by the nymphæ. There was a normal clitoris. LADINSKI (lxvii.) describes the case of a female with well developed mammæ, who had very small vulvæ, a normal clitoris,

a vestibule $\frac{3}{4}$ in. in diameter and $\frac{1}{4}$ in. deep, *no vagina nor uterus*. She had one married sister who had borne children, and another who had an infantile uterus. A similar case of *absence of vagina* is noted by VINEBERG (lxviii.) in which the urethra was abnormally large. The author states that out of 26 cases in the literature of the subject, the urethra is mentioned as having been of unusually large calibre in 11, and in all of these there was total absence of the vagina. In 3 cases where the urethra was stated to have been normal, the vagina was represented by a depression of greater or less depth. (The author does not state whether the enlarged urethra was an acquired condition, consequent upon attempts at coitus, or whether it was congenital.)

BALDY (lix.) deals with the same subject, in connection with the case of a woman of 24, who had well developed mammæ and normal vulva, the nymphæ were rather small, and the hymen apparently intact. There was *no vagina nor uterus*, nor, so far as could be made out, any Fallopian tubes or ovaries. Burrage, he says, has collected 380 cases of absence of the uterus; amongst these are 35 in which autopsies had been obtained. In all these last, whether upon adults or girls, there was noted rudimentary tissue, representing the uterus, generally in the shape of one or two little knobs of tissue the size of hazel-nuts, or a thin band between the rectum and bladder. The ovaries were present in all but six cases, and in the same number the tubes were absent, though when present they were often without any canal. In the discussion on this paper, Dr Hirst mentioned the case of a girl with absence of uterus and vagina, two of whose maternal aunts had never menstruated, and though married, had never been pregnant. It is possible that they may have been similarly afflicted.

SPENCER (lxx.) narrates three cases of *tumours of the internal os*, which caused hydrometra, met with in the examination of 100 uteri of new-born children. He suggests that the tumour is due to a fault in the fusion of the Müllerian ducts, and refers to a paper by Friedlander in the *Arch. f. Gynæk.*, xlv. 634. JUERARD (lxxi.) records the case of a female who had had several miscarriages, in whom the *uterus* was *double* and the *vagina* single. When she came under examination she was three months pregnant in one side of the uterus and seven in the other.

VIII. EXTREMITIES.

MARION and BARON (lxxii.) give an account of a man both of whose hands and feet were symmetrically *hexadactylous* and also *syndactylous*. The hand had a postminimus, and the fourth and fifth fingers were united by a web. The sixth finger was an appendage to the fifth, and had no metacarpal, and the first phalanx was much reduced. This digit possessed no muscles and no tendons, all of these going to the fifth. The foot had a postminimus, which lay on the dorsum on the right side, and was on both better formed than that of the hand. It possessed a metatarsal, united at its base to that of the

fifth, which thus appeared to be bifurcated, and three normal phalanges. It articulated with the cuboid, from which the process to which the peroneus brevis is connected was detached, and lay as a separate ossicle, articulating with the cuboid, on one side, and with the cuboid and metatarsal on the other. It had no slip from ext. brev. dig., but it had from ext. com. and per. brev. and from flex. brev. It had no humbrical. The plantar muscles were thus arranged:—Abd.m.d. (a) to what represents tubercle of 5; (b) to external border of 5; (c) to postero-external part of first phalanx of 6. Opponens, to 6. Flex. brev. do. There were two additional interossei, viz., a palmar for 6 and a dorsal for 5. PÉRAIRE (lxxiii.) describes a case of hexadactyly in all four members, the additional digit in each case being a functional postminimus. When examined by the Röntgen rays it was seen that in the case of the hand the unciform had three facets for 4, 5, and 6.

BOINET (lxxiv.) states that in spite of the distance over which atavism has to travel, it has been accepted as the probable explanation of *polydactyly*. If this theory is true, then he thinks there should be a chain of bony elements between the postminimus and the pisiform, which chain his radiographs have not demonstrated. He gives 17 new observations, and gives it as his opinion that radiographs prove that a process of dichotomy is at the bottom of all these cases, and that this is caused by nervous action, since such abnormalities are frequently hereditary and symmetrical. A similar influence exists, he thinks, in cases of ectrodactyly. He describes a case of ectrodactyly with two digits, which, he thinks, shows that the pisiform is independent in its origin. This bone was normal, whilst all the other bones of the carpus and metacarpus had undergone alteration. If, he says, the pisiform is the vestige of a ray of a primitive fin, it ought to be atrophied in cases where the last three metacarpals and their corresponding digits are completely absent. PFITZNER (lxxv.) describes a case of *polydactyly* in which, during life, the individual appeared to possess a very broad thumb, with a bifid extremity. On dissection, however, it was found that included with the pollex was a supernumerary index, the latter being double from the metacarpal downwards, and the middle phalanx of the additional digit articulating with the end of the proximal phalanx of the pollex. The terminal phalanx of the true pollex was peculiar, being constricted in the centre, and thus consisting of two parts, viz., a fairly normal terminal phalanx with a basal part united to it, this basal part, according to the author, being the middle phalanx of the thumb. He considers that the dimerism of the pollex and hallux is due to the fact that the distal and mesial phalanges have fused to form a typical but large end phalanx, and that in this case the bones have been, so to speak, caught in the act, being united but not assimilated.

TISSOT (lxxvi.) gives an account of a family of *sexdigitate individuals*, consisting of three children, thus provided on all four members. All the digits were functional. An account of the radiographic examination is given.

JOACHIMSTHAL (lxxvii.) narrates five cases of *brachydactyly with hyperphalangy*, a condition first called attention to by Leboucq (*Bull.*

de l'Acad. R. de Med. de Belgique, 1896, 544). (1) On both sides the index and medius were unduly short, and in each case the former possessed four phalanges. (2) Index and medius brachydactylous on both hands, and the right index had four phalanges. (3) Brachydactyly of all fingers (not thumb) on both hands. (4) Abnormally short metacarpal 4 on both sides. (5) A similar condition of metacarpals 5. He mentions that he has seen a case of what he thought was a trimerous pollex in a child *æt.* 2 years. A radiograph showed that the metacarpal had a distal epiphysis, from which he concludes that it was a case of double index with suppression of thumb. (The reporter ventures to submit that this case might be interpreted in quite a different manner.)

JAYLE and JARVIS (lxxviii.) describes a case in which *ectrodactyly* and *syndactyly* of the right hand co-existed with double *ectrodactyly* of the feet.

DUROQUET (lxxix.) has examined the condition of *congenital luxation of the hip-joint* by means of radiography. The epiphysis of the head of the femur is abnormally small, a fact which he thinks is due to improper vascular supply. WICHART (lxxx.) describes a case of *gigantism of the great toes*. The right showed some signs of reduplication, having a normal nail, and a second of a rudimentary nature. The left had an additional bone, which received a second tendon from the flexor. There was no history of heredity. WEISSENBERG (lxxxi.) describes a case of *congenital malformation of the limbs* in a child *æt.* 4 years. All the extremities were twisted, there was a large scar on the right shoulder, and several atrophic areas in the skin. The condition is attributed to an almost complete absence of liquor amnii, which was noted at birth. MORESTIN (lxxxii.) describes a case of *congenital lipoma* of the inferior gemellus removed from a female *æt.* 23.

STOLZ (lxxxiii.) describes a case of twin pregnancy, where one child was flattened and macerated, and the other had *gangrene of the leg* from constriction. Had the pregnancy gone on to the full term, this would have been a case of congenital amputation.

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(The reporter wishes to express his acknowledgments to the abstracts in the *British Medical Journal* and *American Journal of Obstetrics* for some of the above.)

CORRECTION.—Professor Thane has called my attention to a passage in Hyrtl's *Onomatologia Anatomica*, in which he correlates the name *basilik* with the inner vein of the arm (p. 69). The error, therefore, to which I referred is Hyrtl's, and did not originate with the Editor of "Quain." I am grateful to Professor Thane for the correction. I had only consulted the work quoted in my former paper, and omitted to look in Hyrtl's later work.

ALEX. MACALISTER.

FEMALE

MALE

PLA7



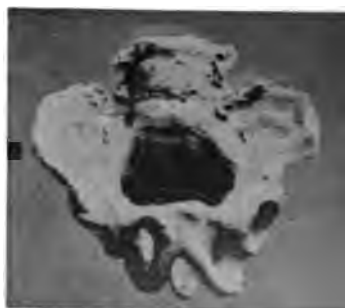
VII Month



VI Month



V Month



IV Month



FOETAL PELVES



FEMALE

MALE



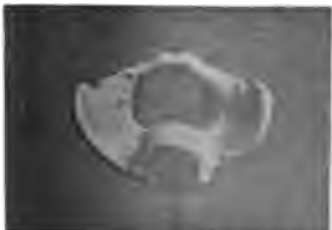
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VI Month



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FOETAL PELVES

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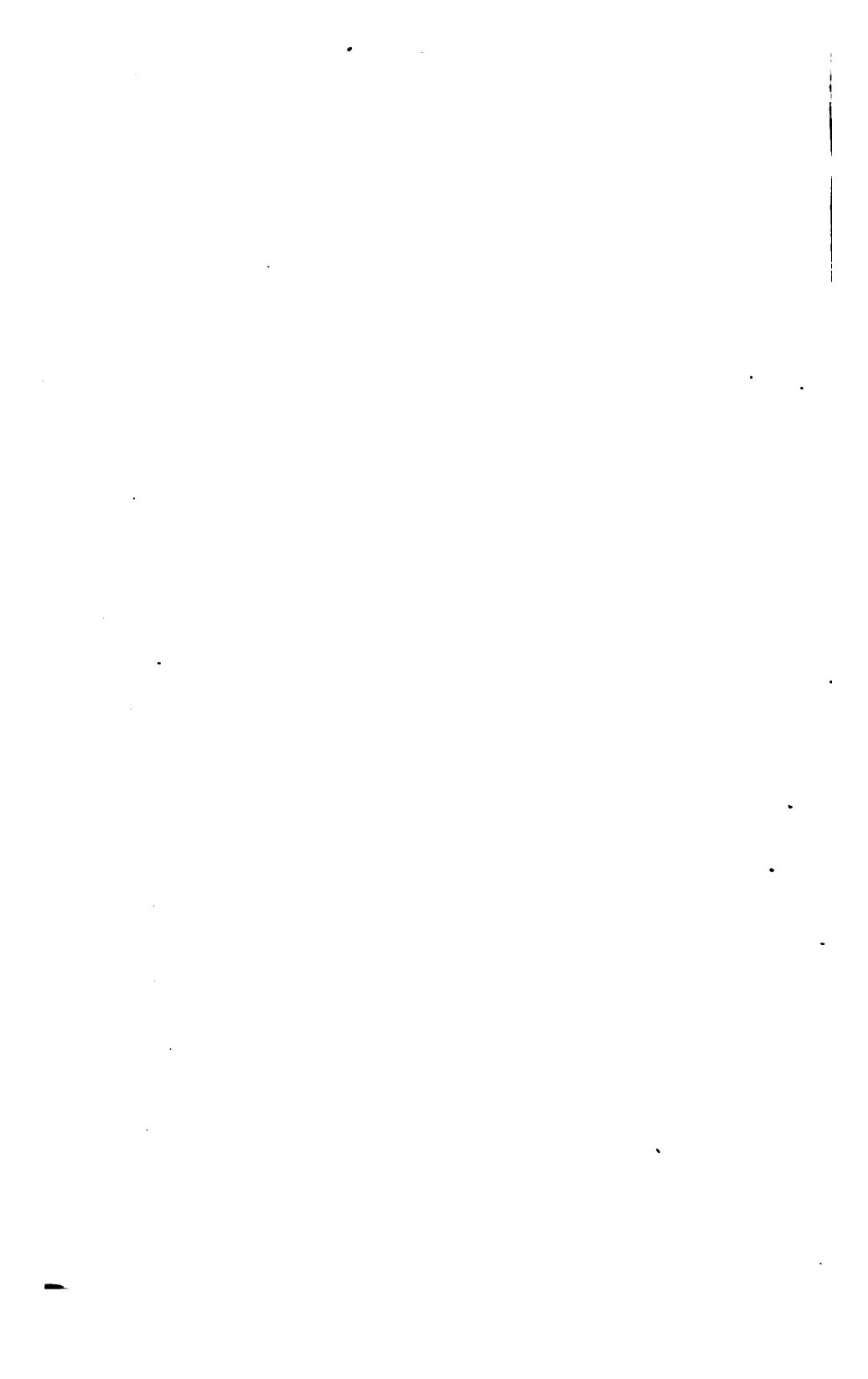


V Month

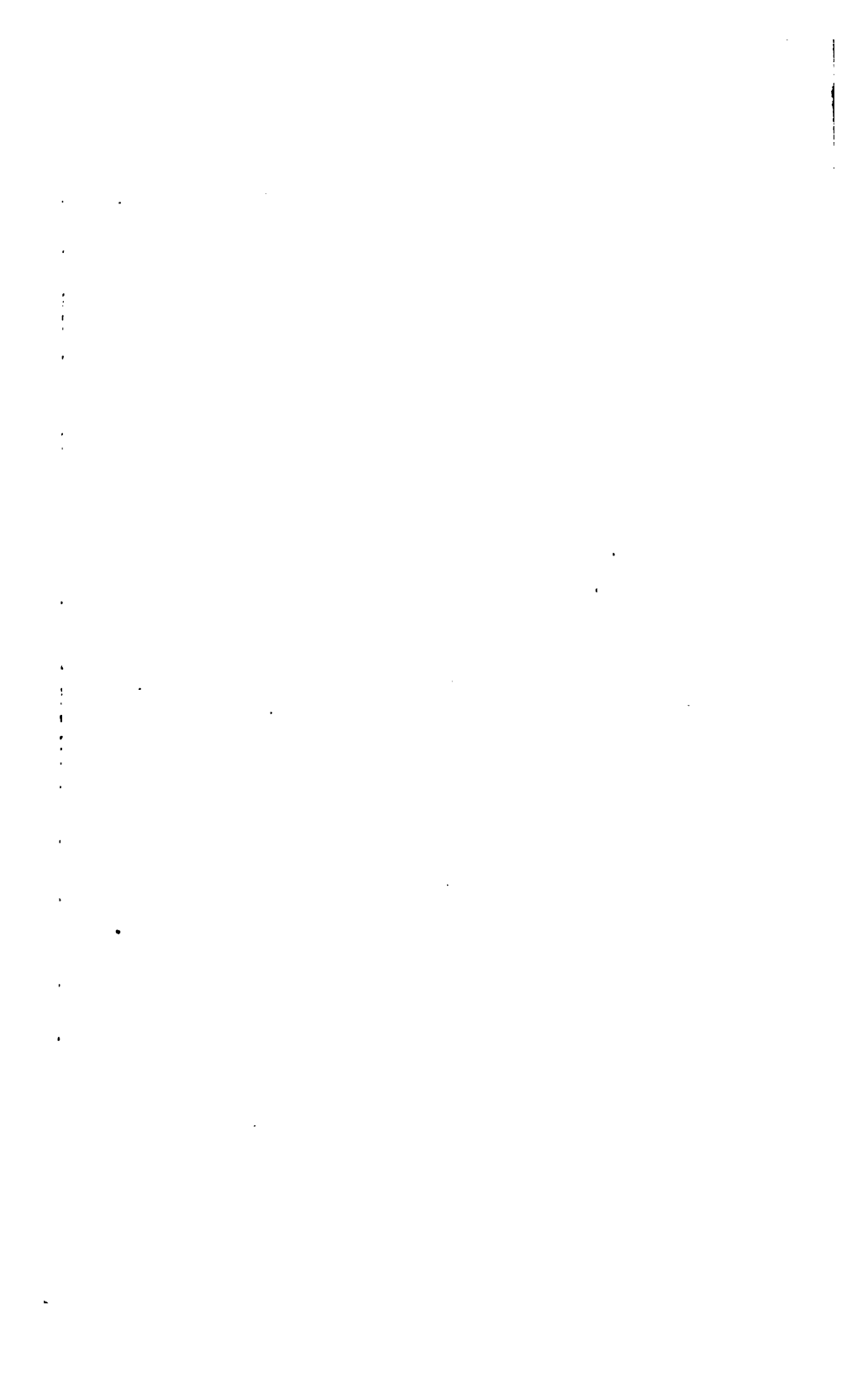


IV Month

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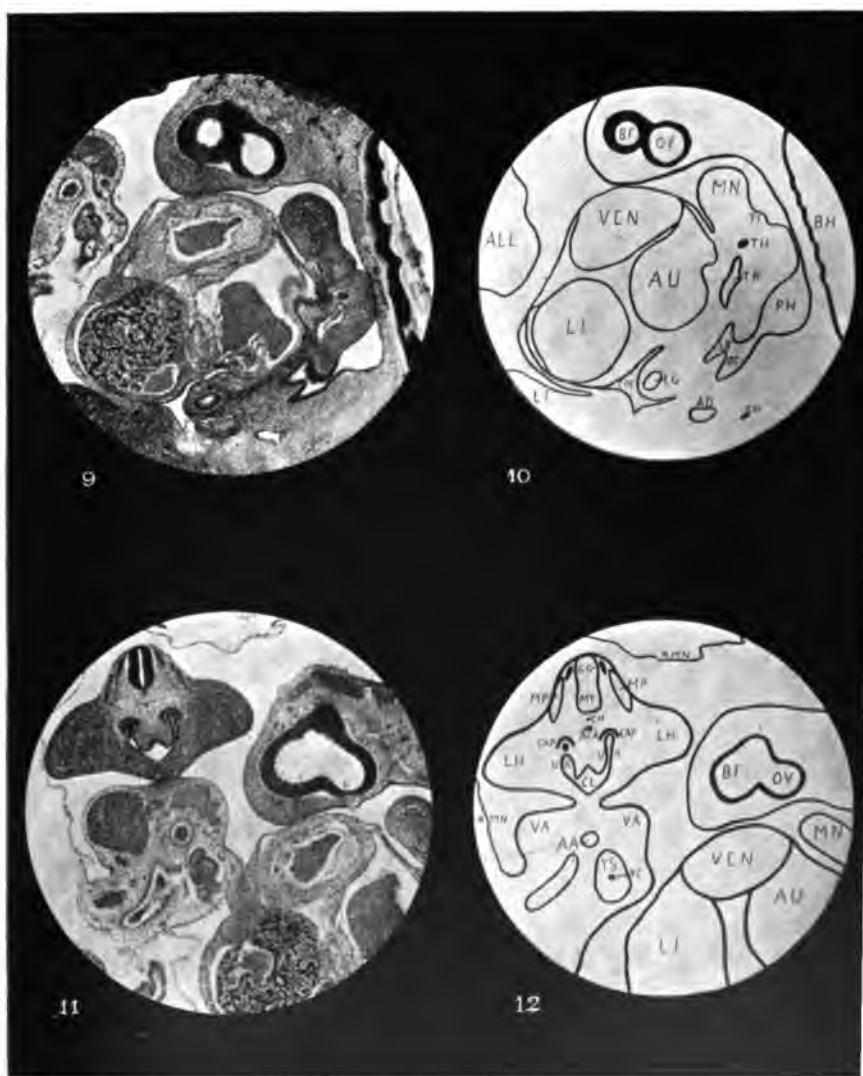








HUMAN EMBRYO.



HUMAN EMBRYO.

FEMALE

MALE



VII Month



VI Month



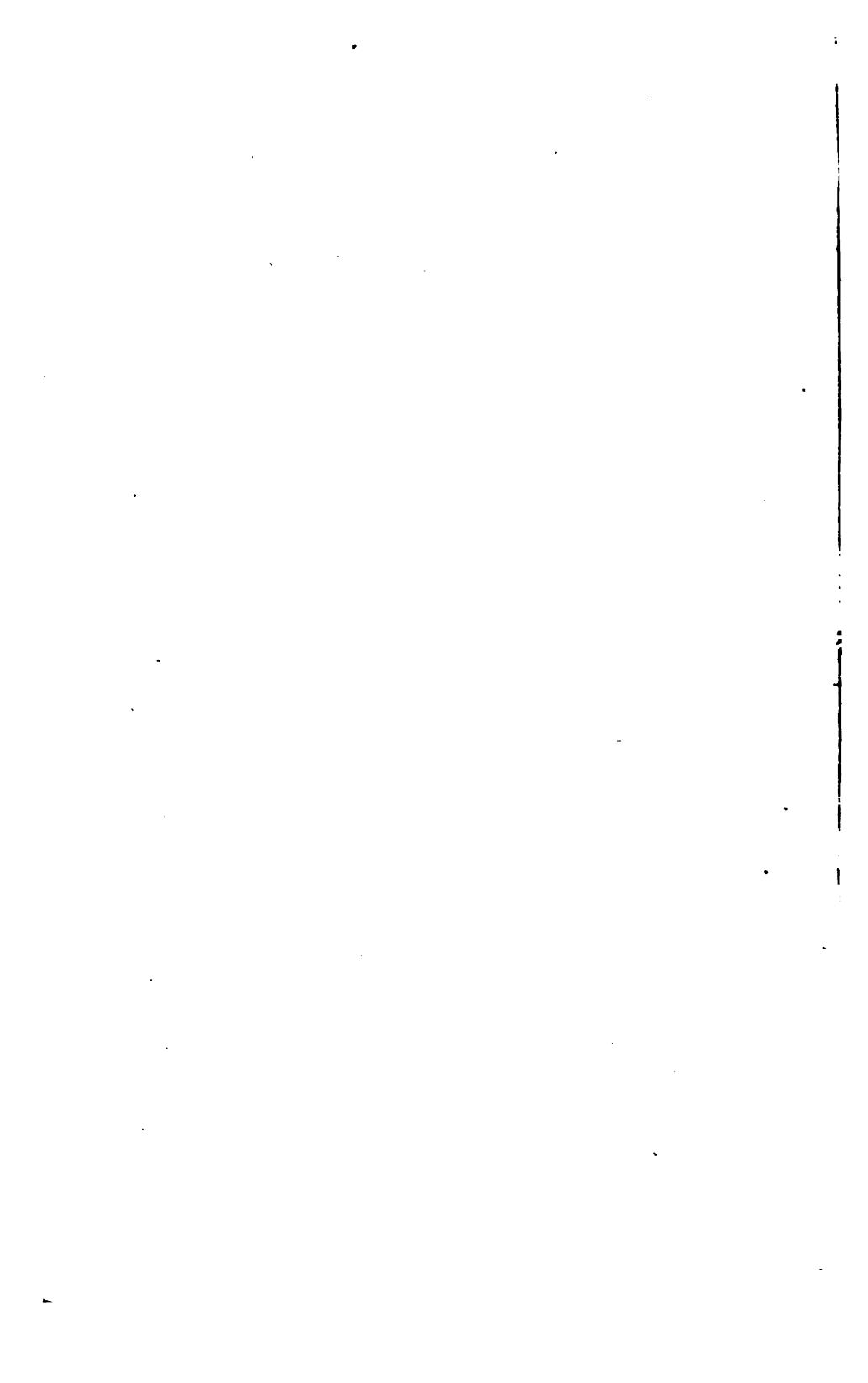
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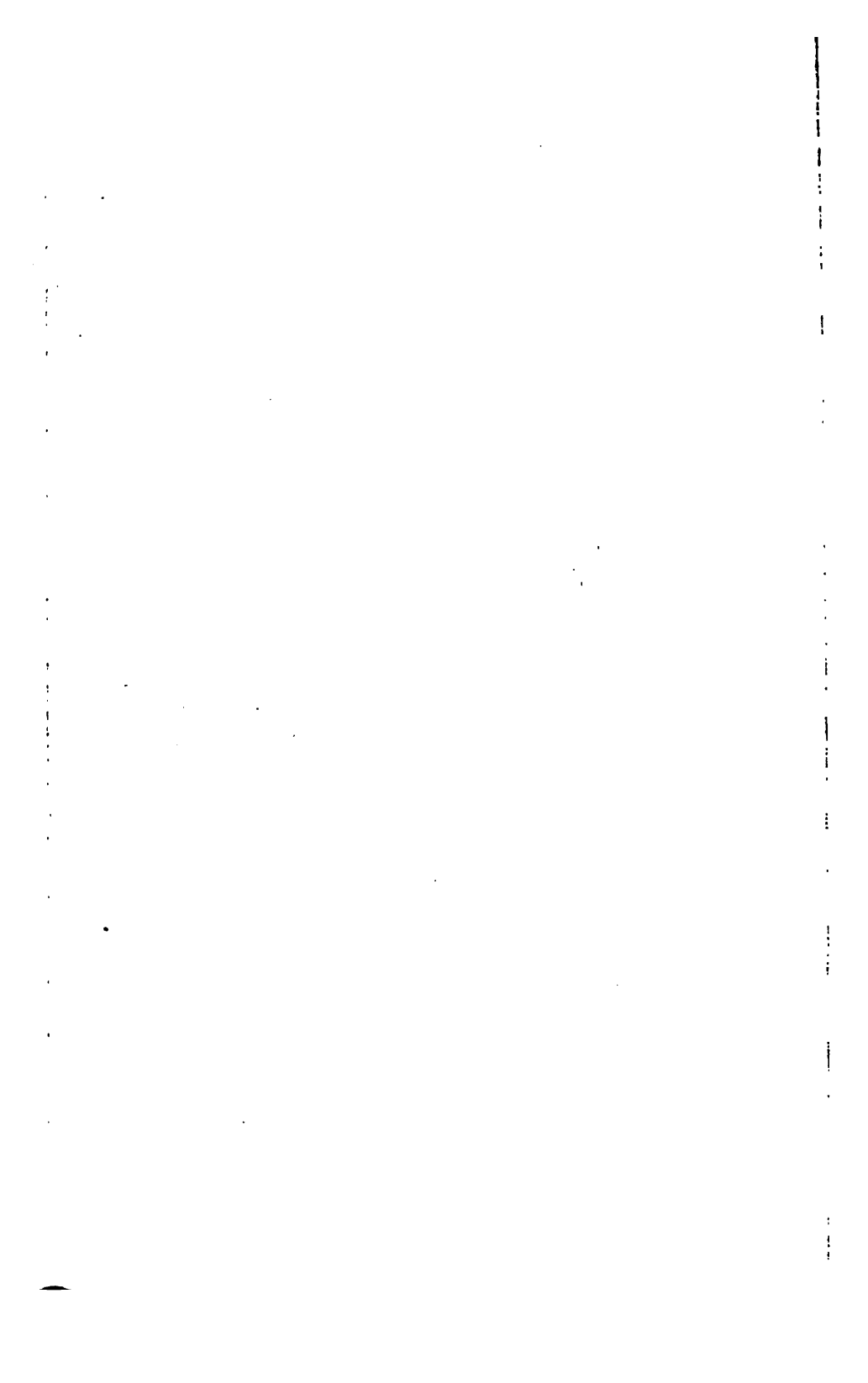
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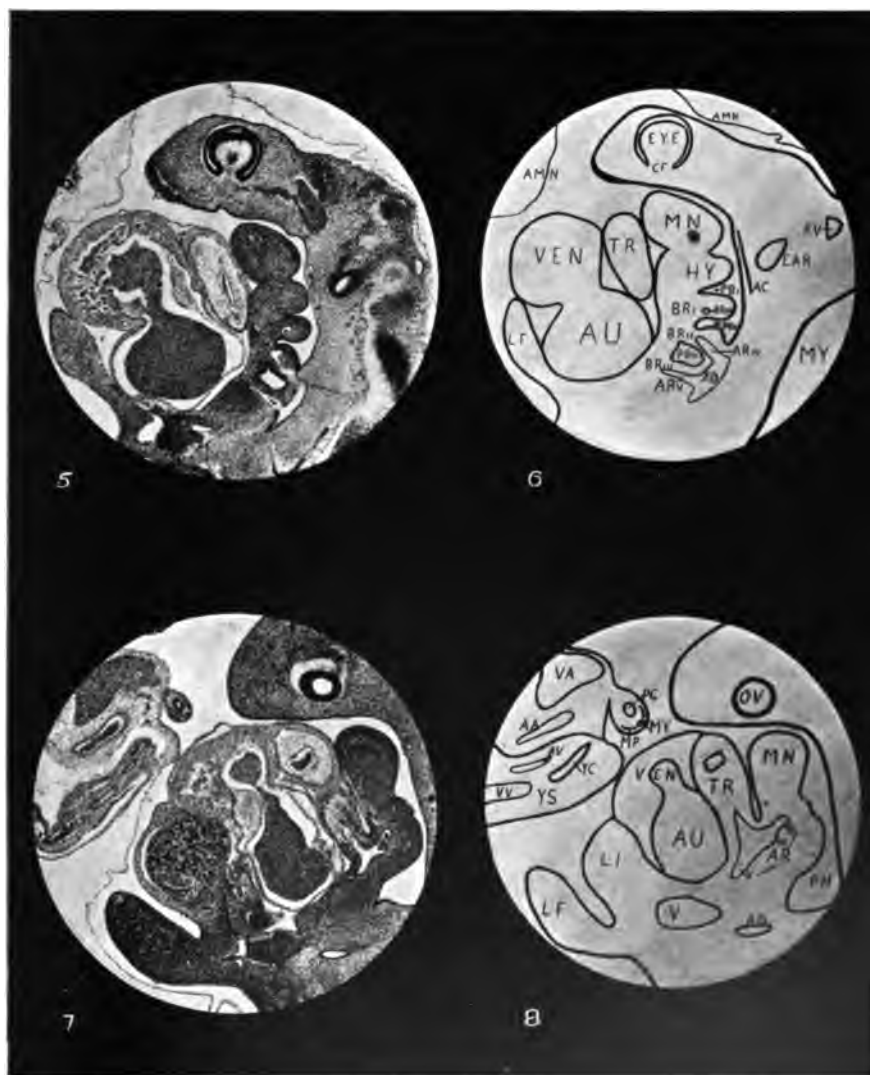


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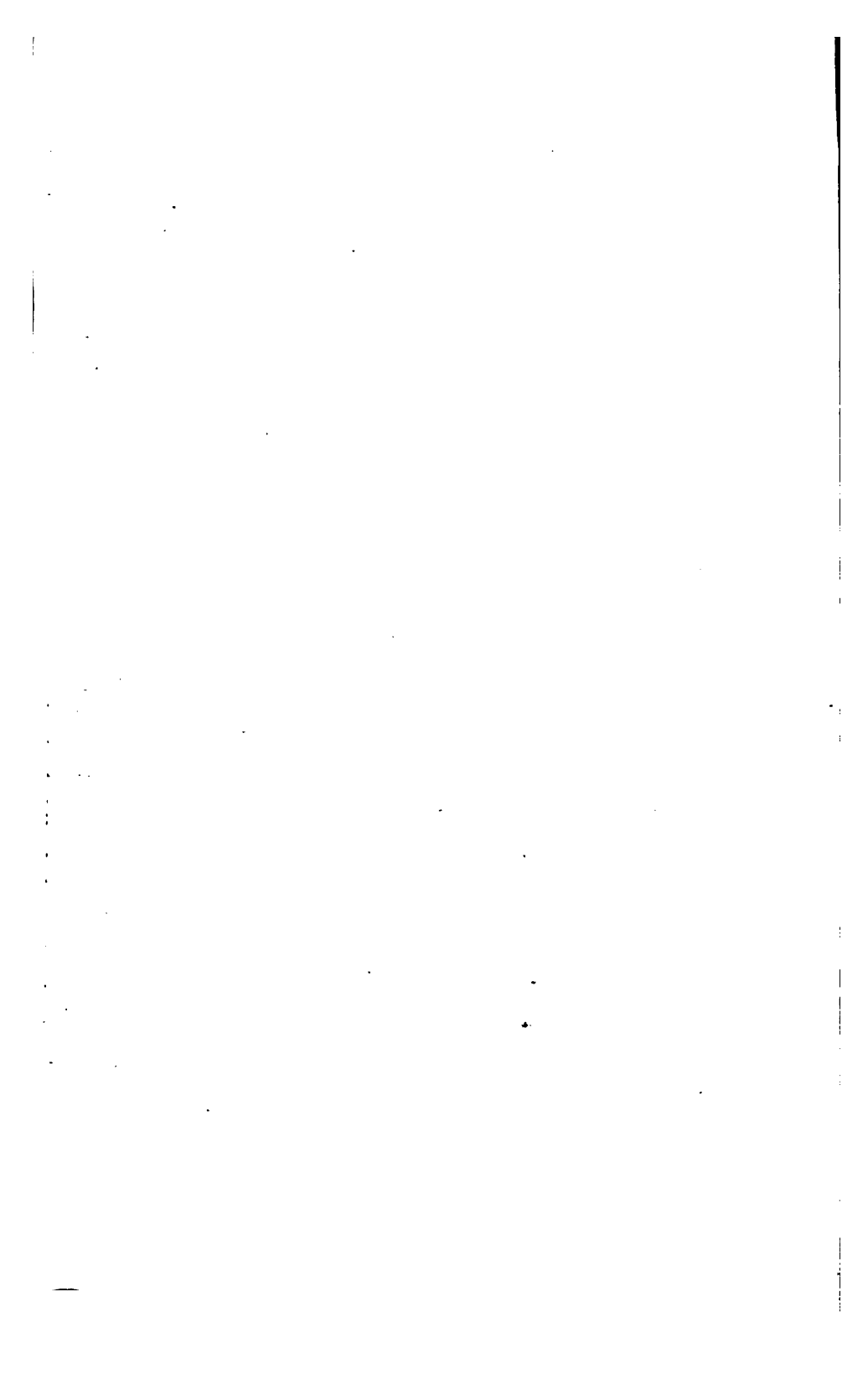








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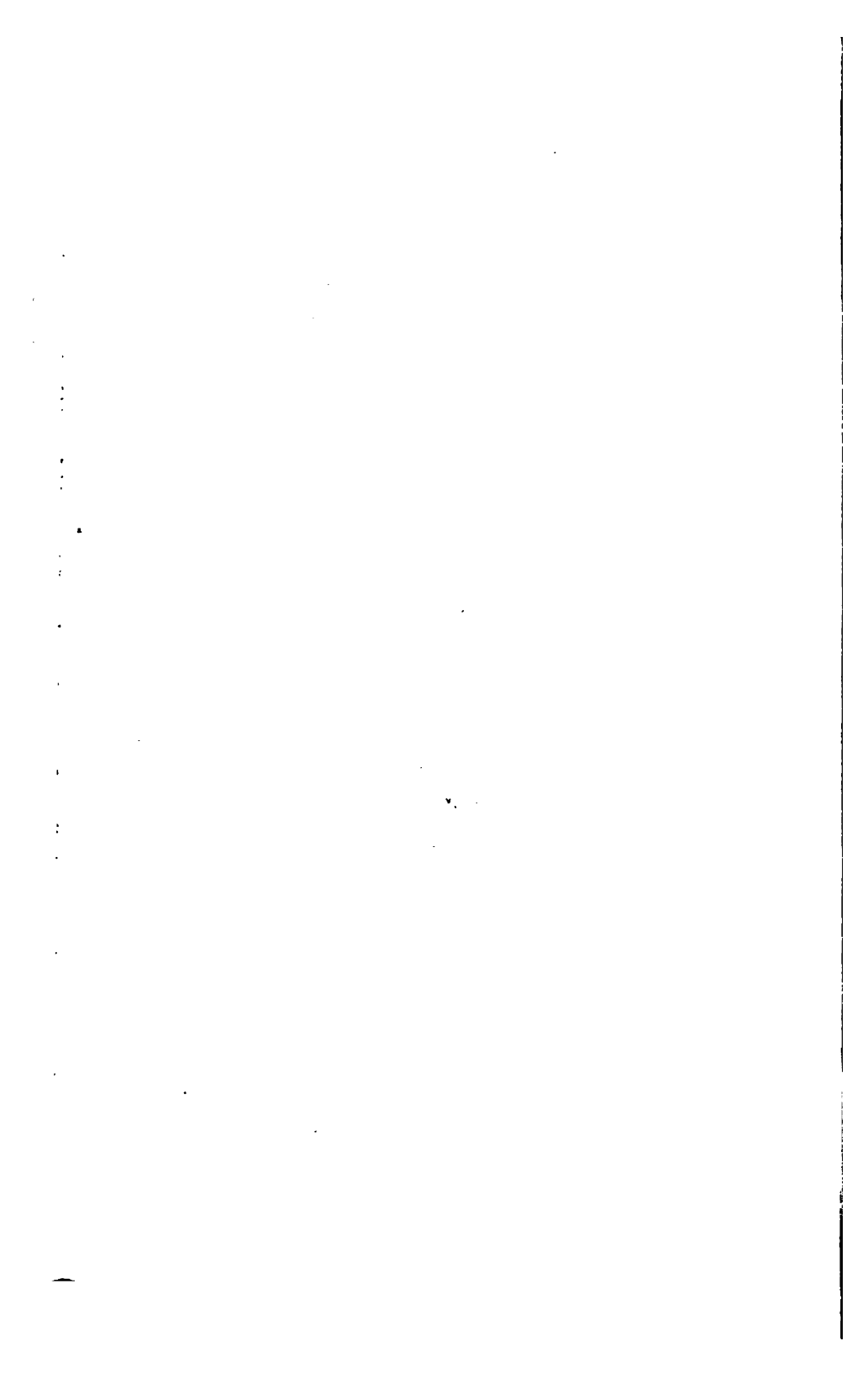


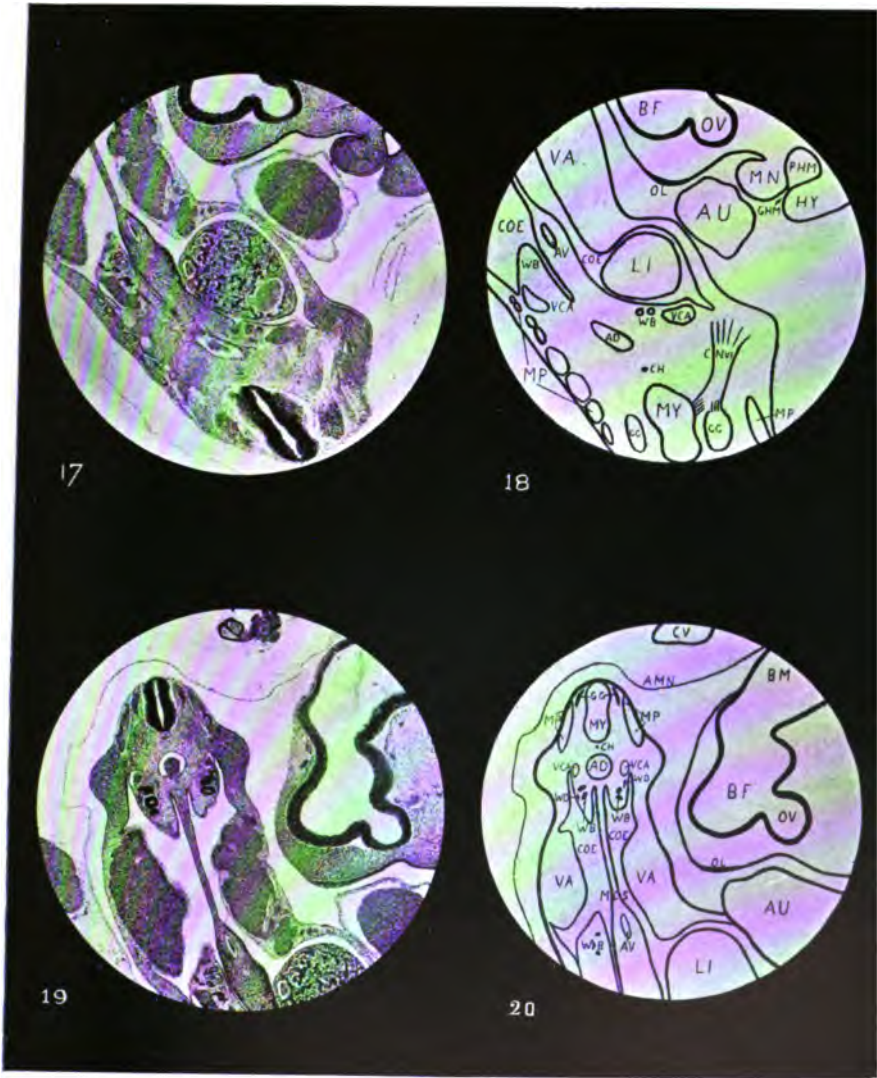


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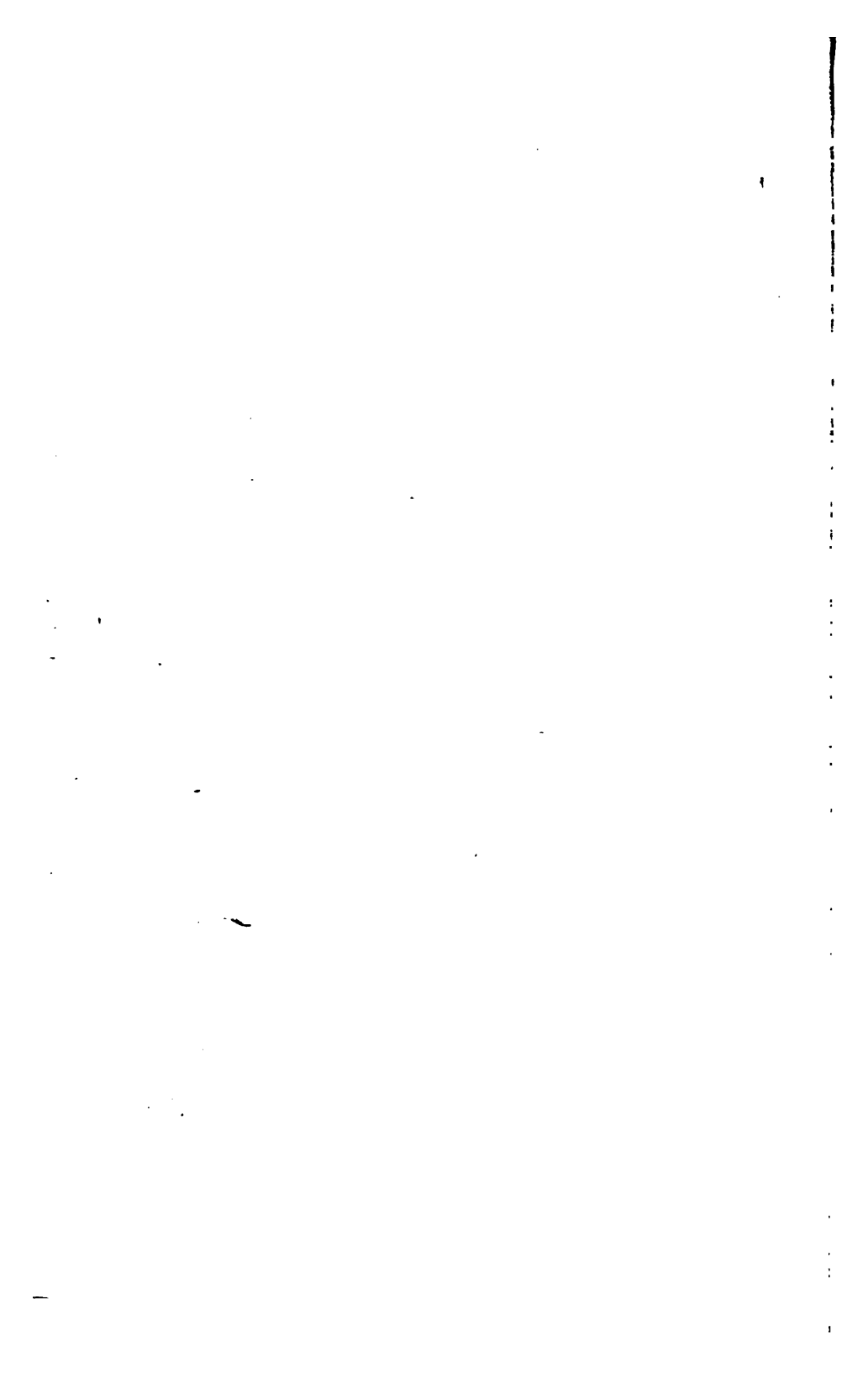


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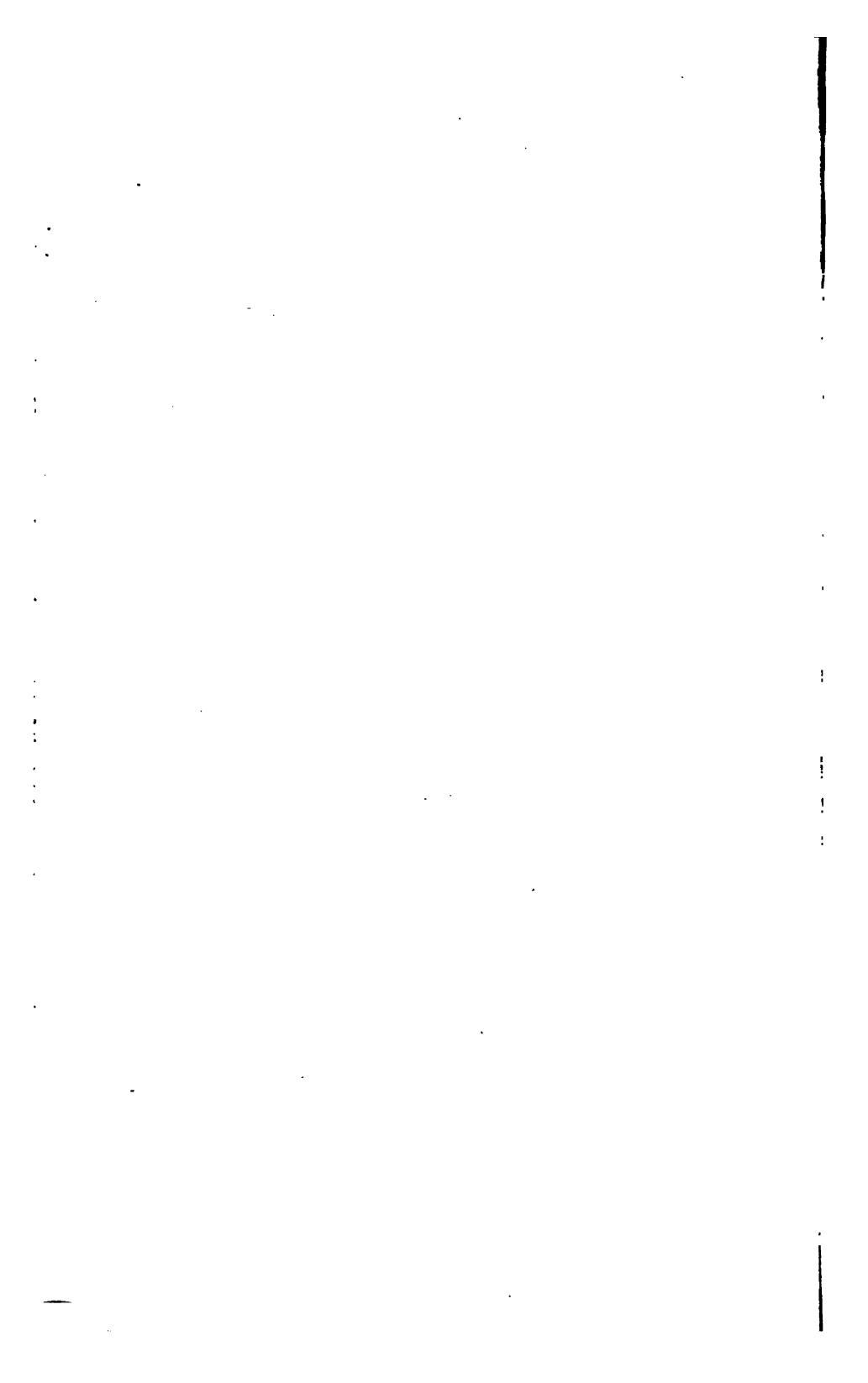


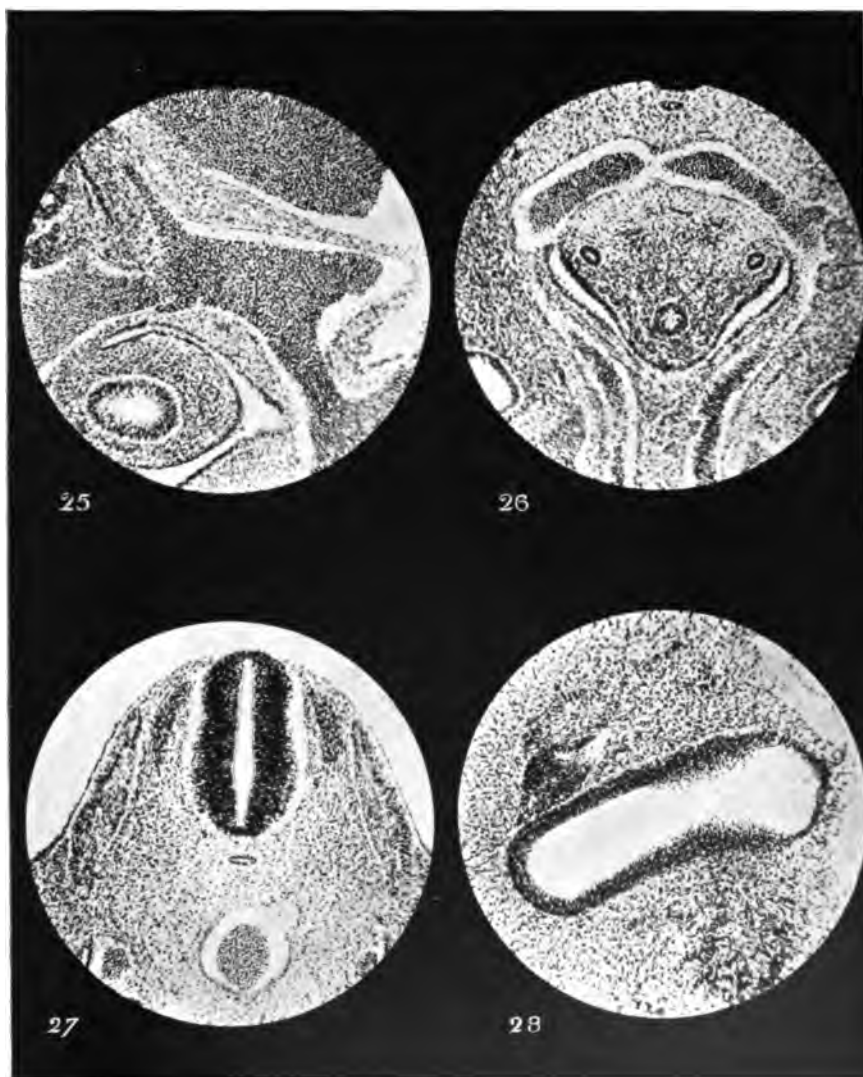
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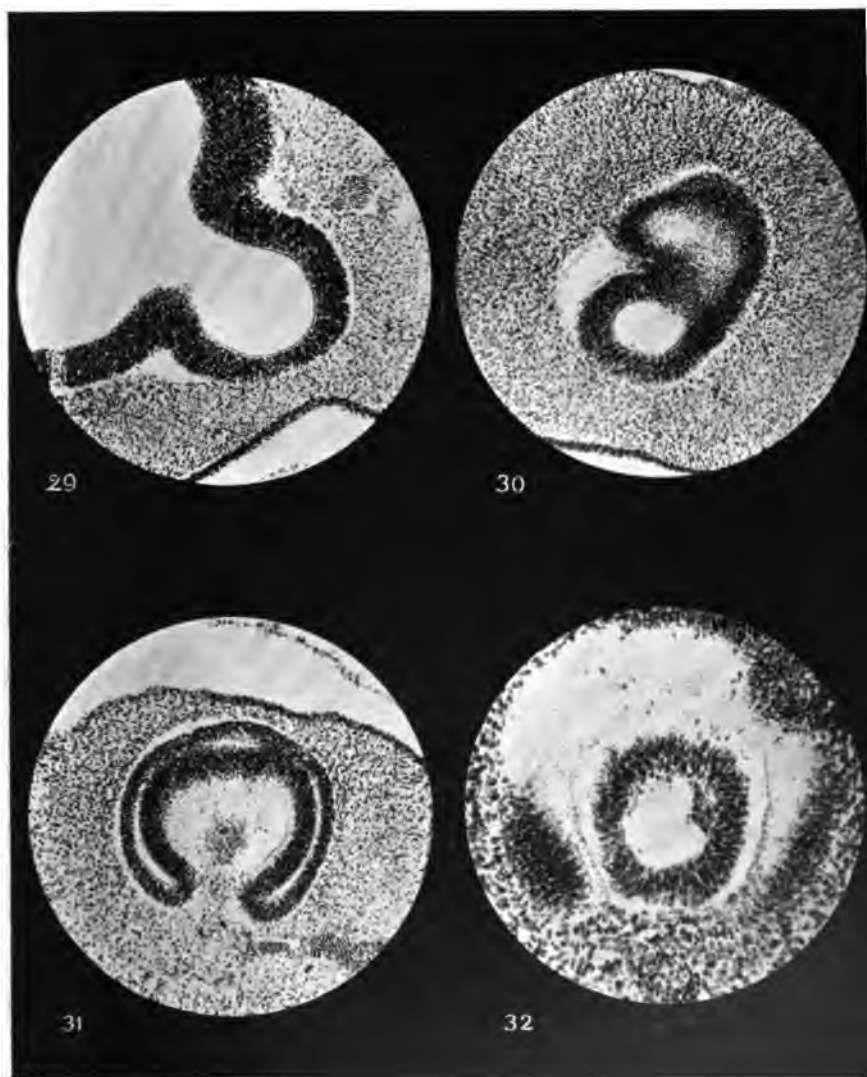


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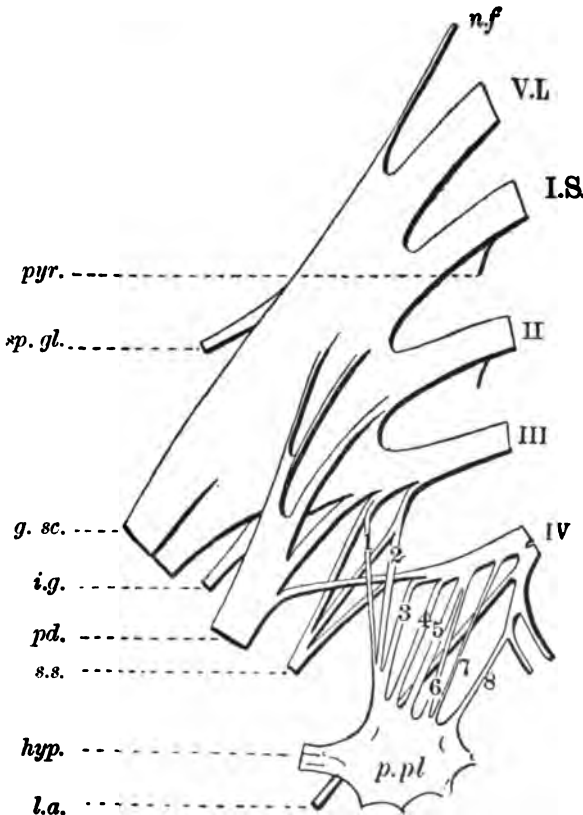


FIG. 1.—Subject, 'M,' right side. (♀ 54 c.m.)



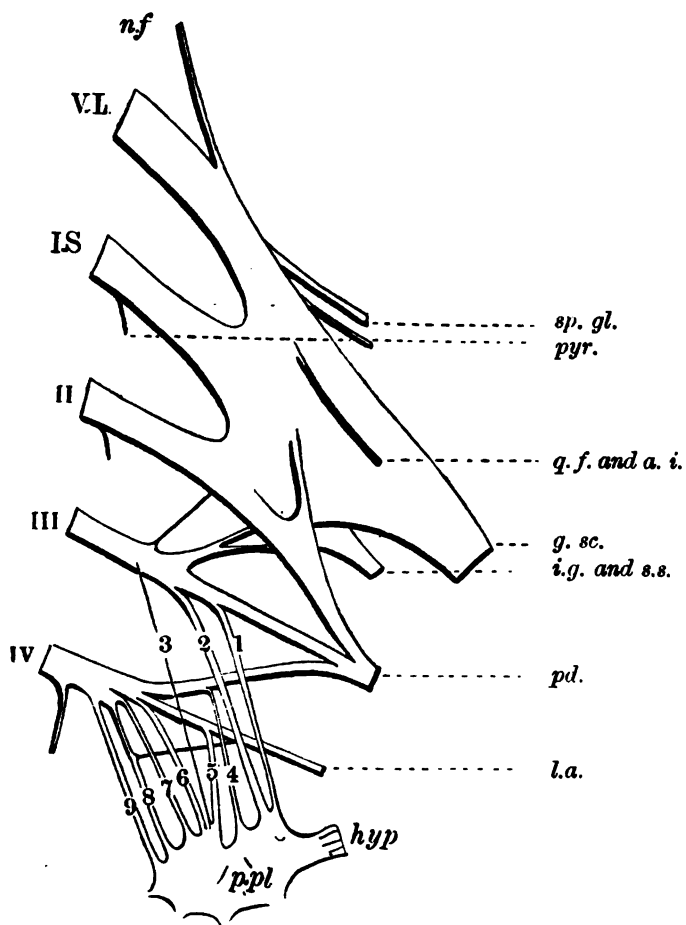
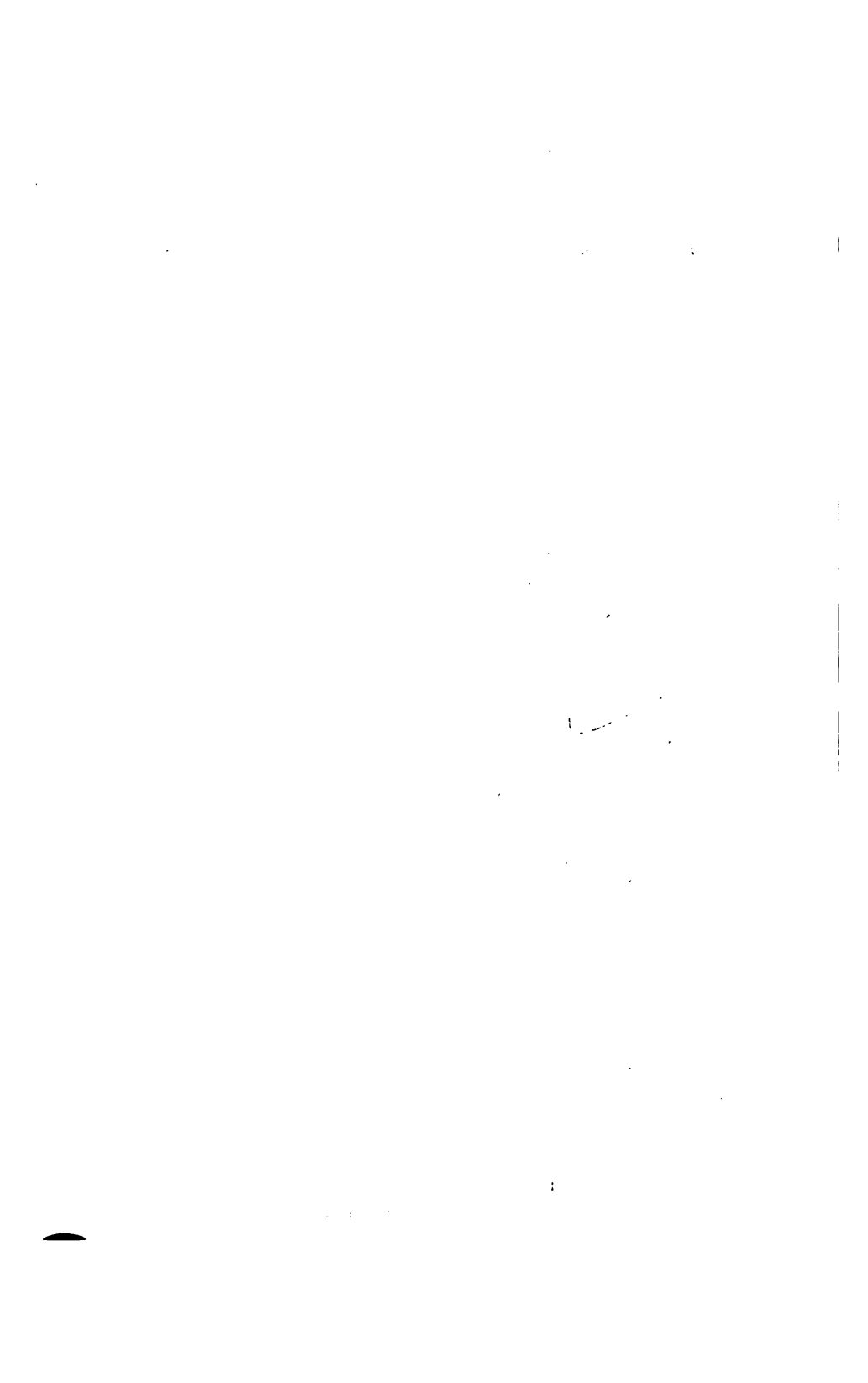


FIG. 2.—Subject, 'M,' left side. (♀ 54 c.m.)



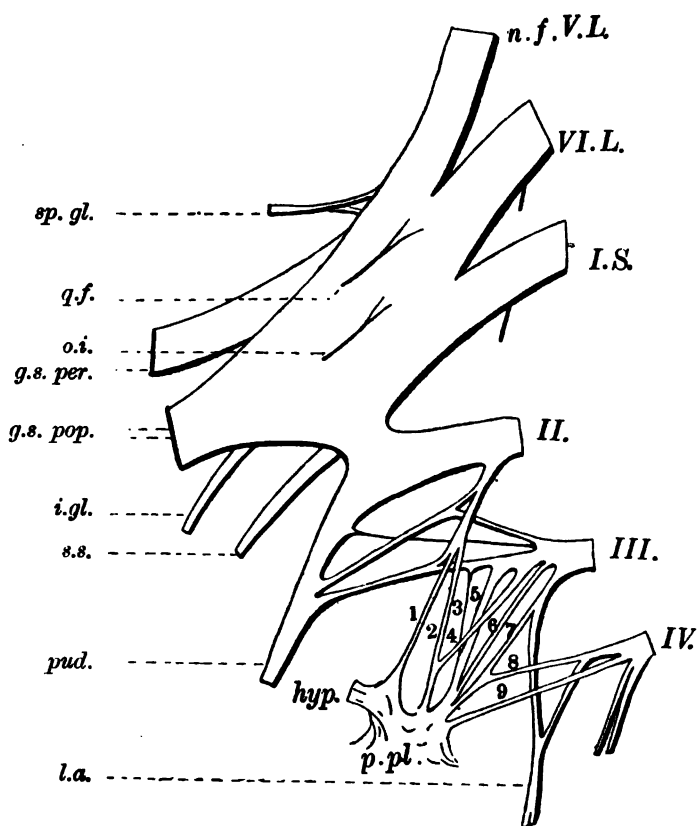


FIG. 3.—Subject, 'G,' right side. (♂ 50 c.m.) XII. Rib absent.



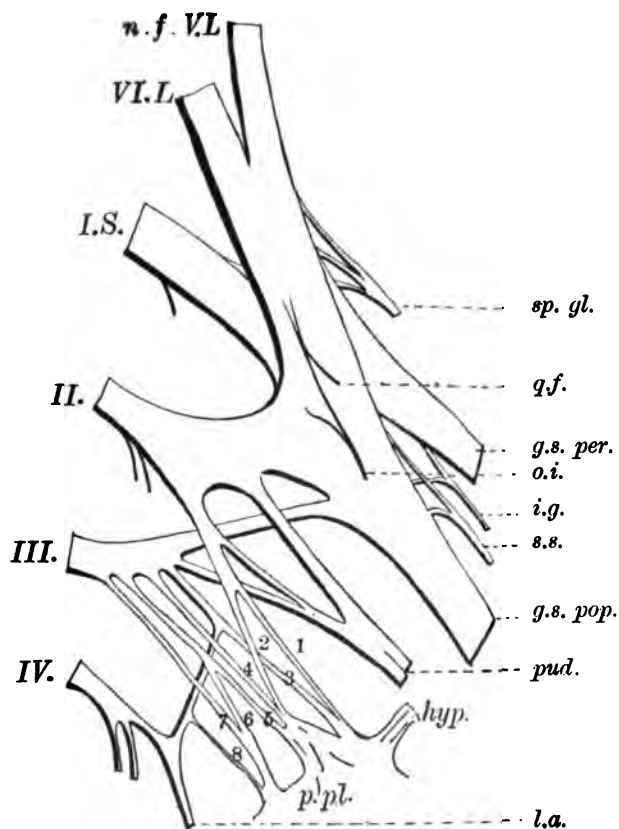


FIG. 4.—Subject, 'G,' left side. (♂ 50 c.m.) XII. Rib absent.

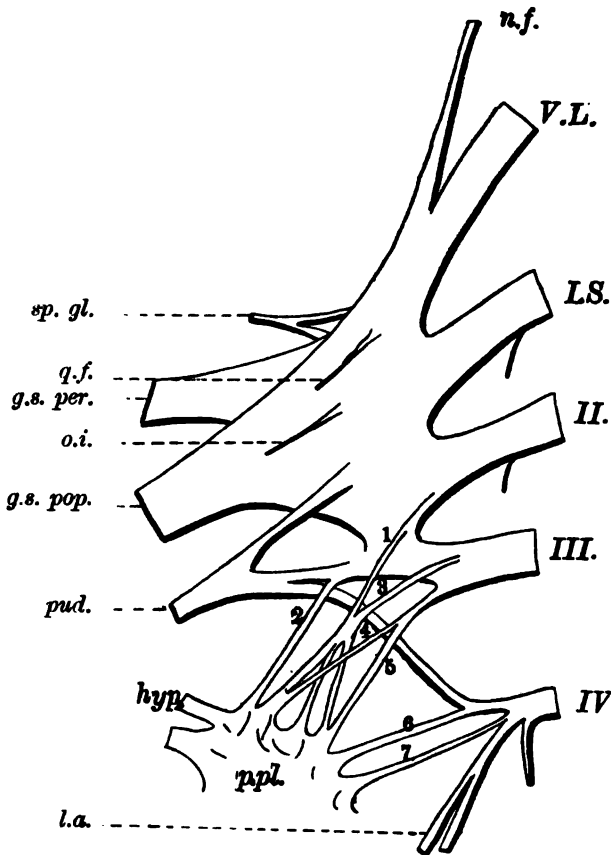
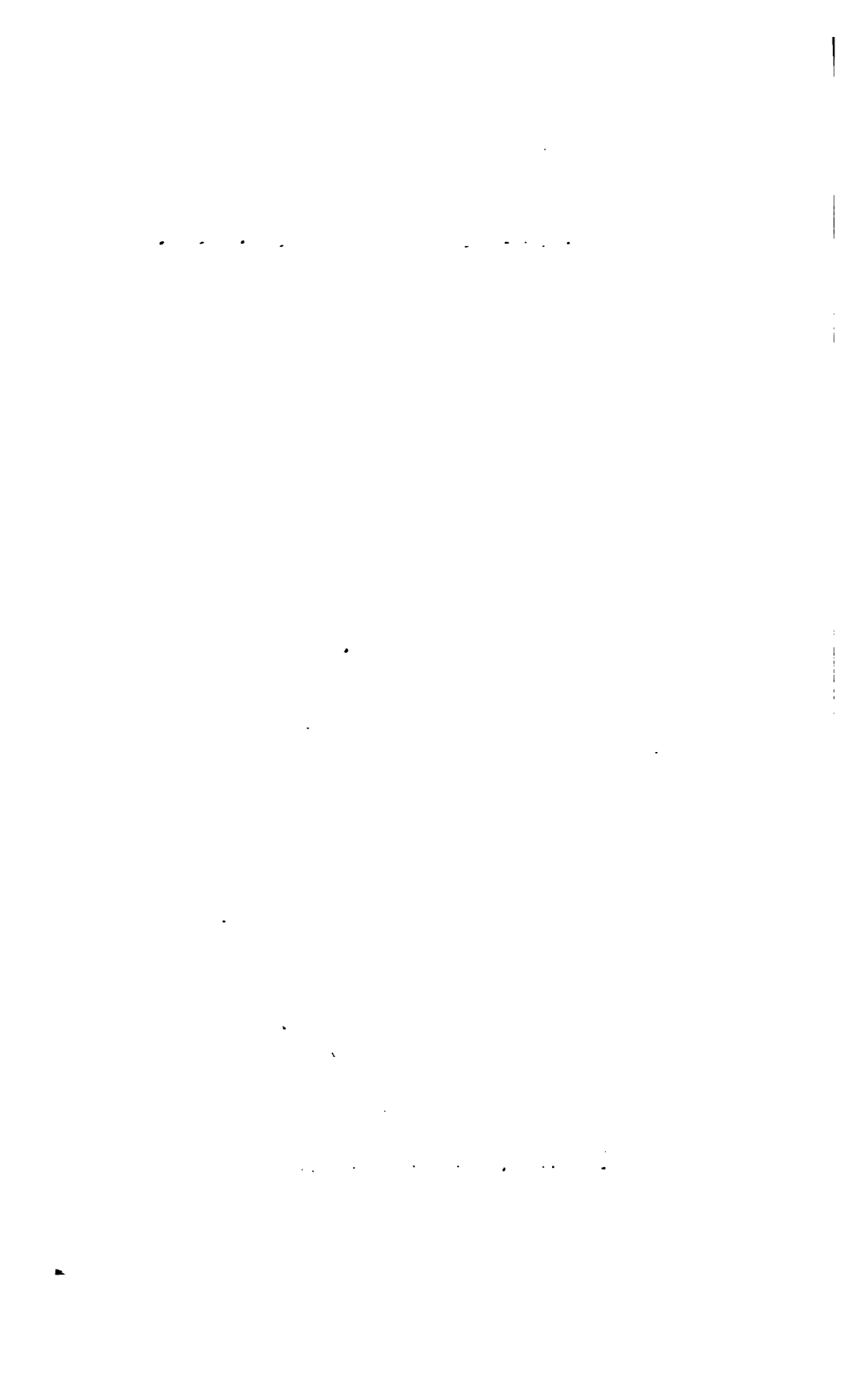


FIG. 5.—Subject, 'H,' right side. (♂ 46 c.m.)



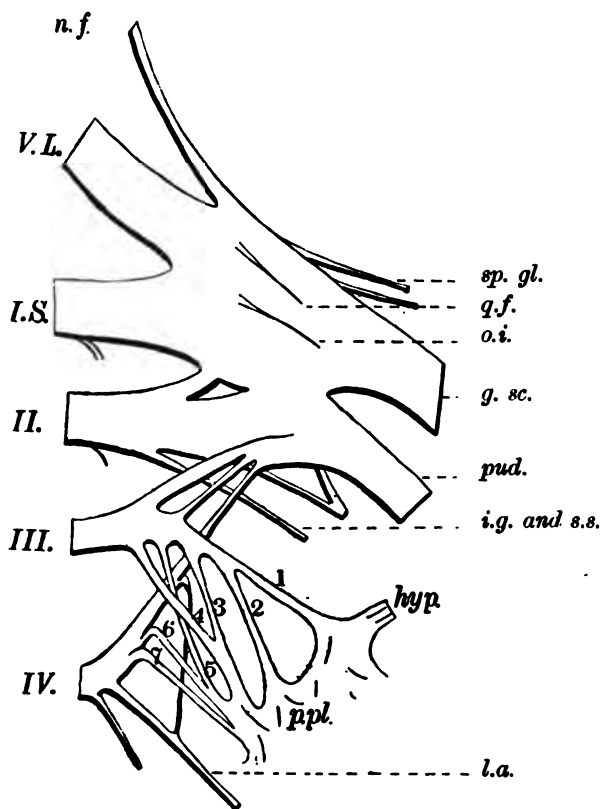
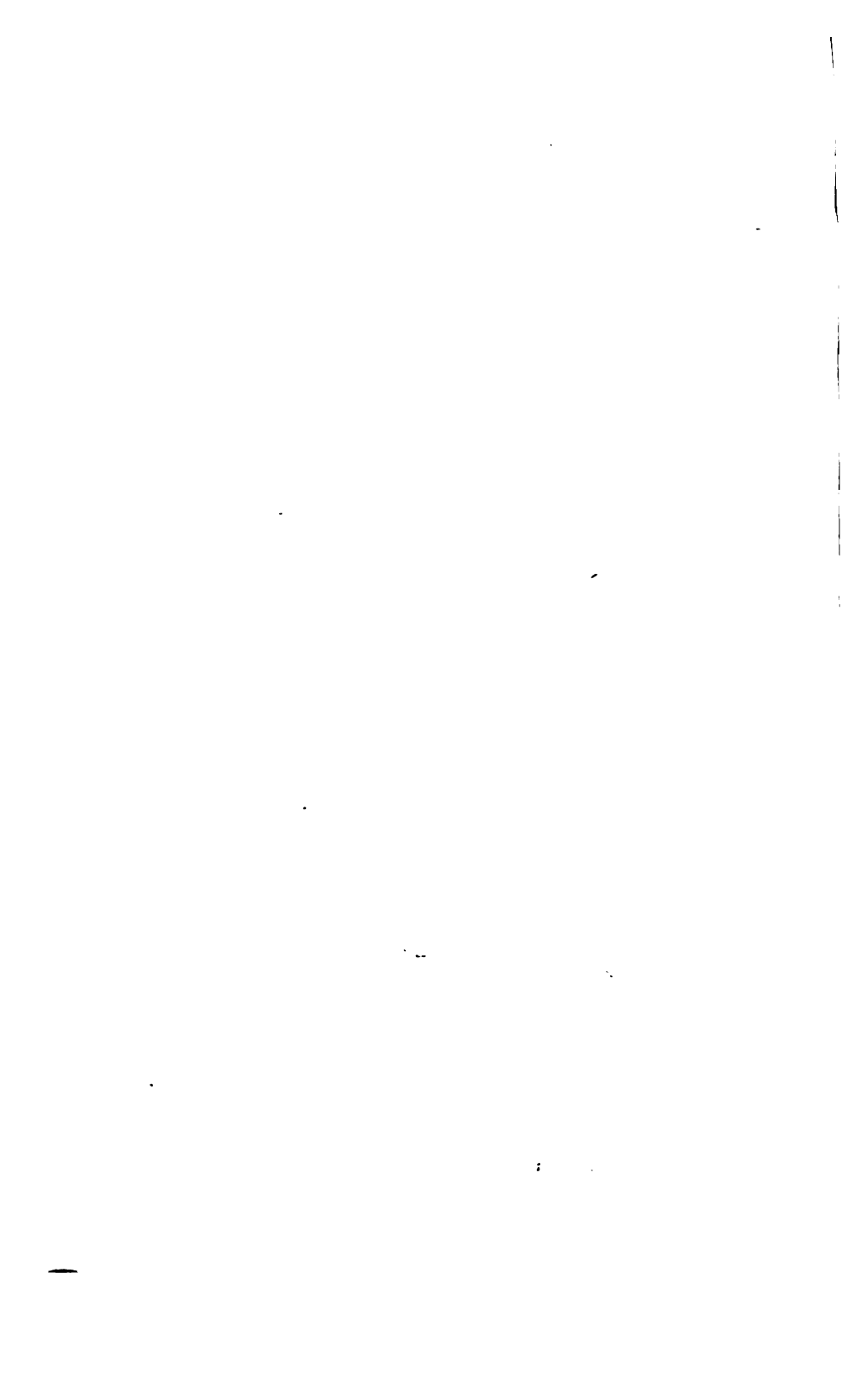


FIG. 6.—Subject, 'H,' left side. (♂ 46 c.m.)



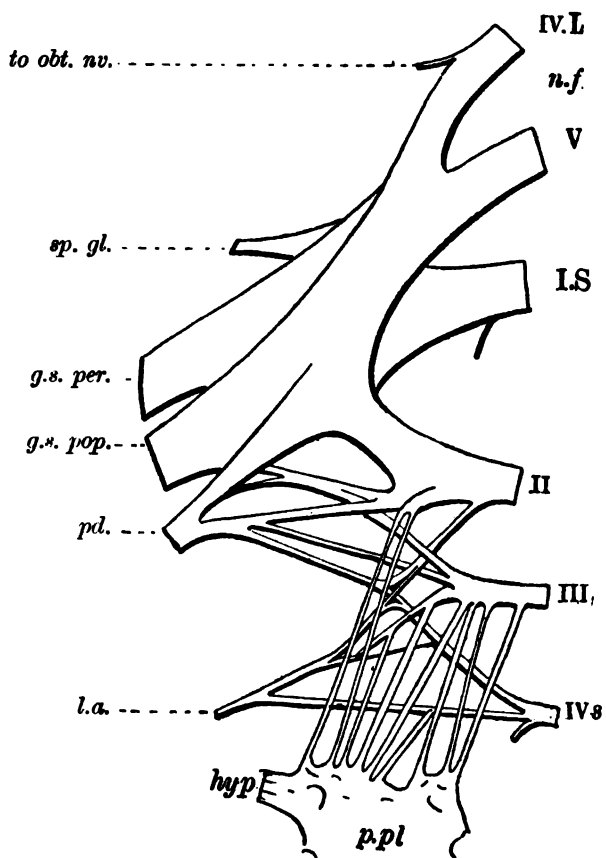


FIG. 7.—Subject 'N,' right side. (♂ 53 c.m.)

N.B.—The numbers of the rami are not inserted; they should read from left to right:—No. II., 1 and 2; No. III., 3, 4, 5, 6, 7, and 8; No. IV., 9.



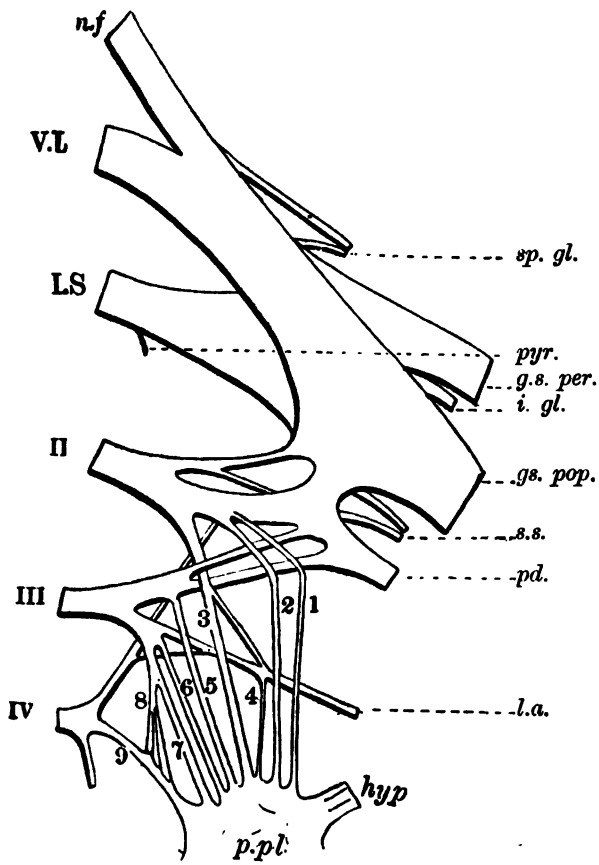


FIG. 8.—Subject, 'N,' left side. (♂ 53 c.m.)

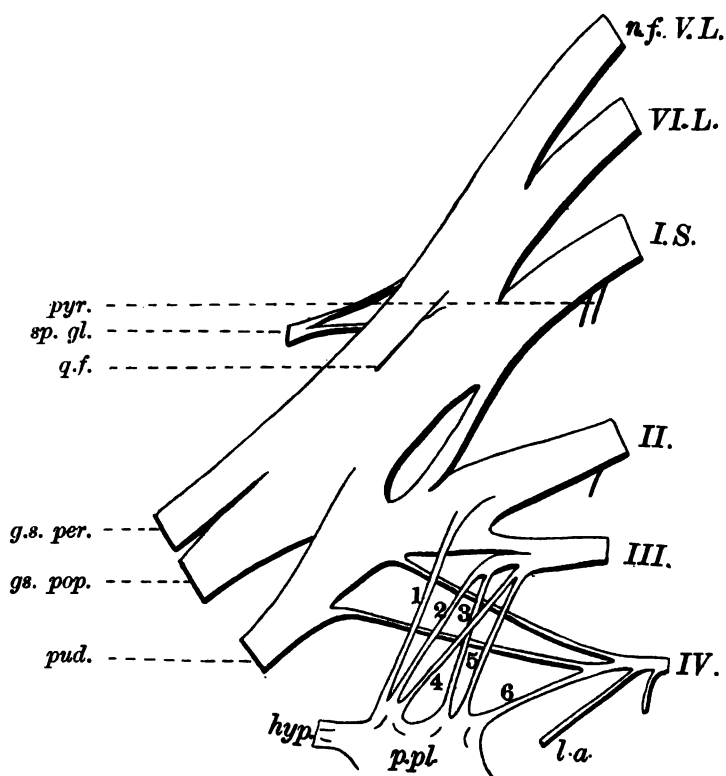


FIG. 9.—Subject, 'K,' right side. (♀ 39 c.m.)
XII. Rib absent.

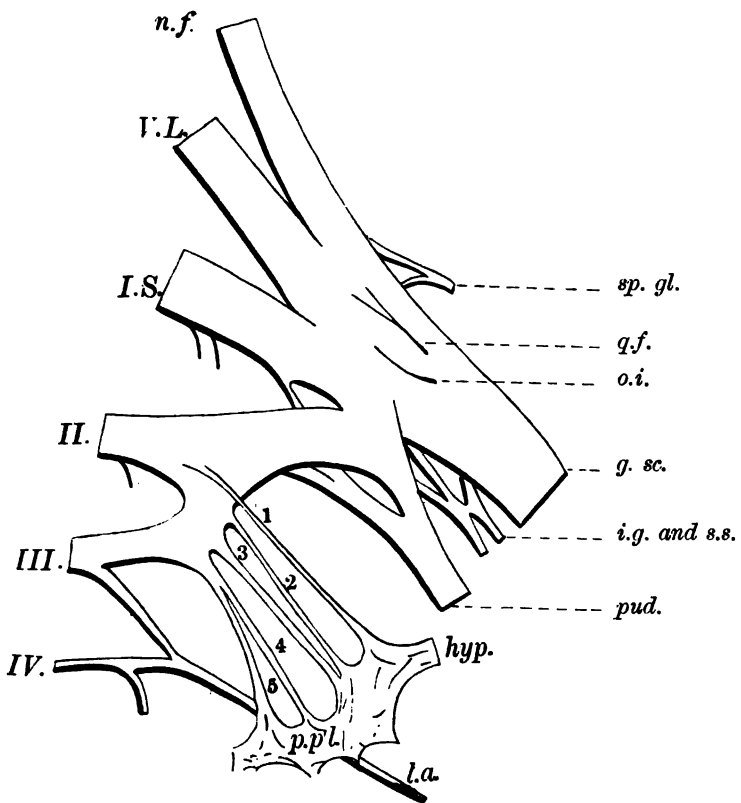


FIG. 10.—Subject, 'K,' left side. (♀ 39 c.m.)
XII Rib absent.

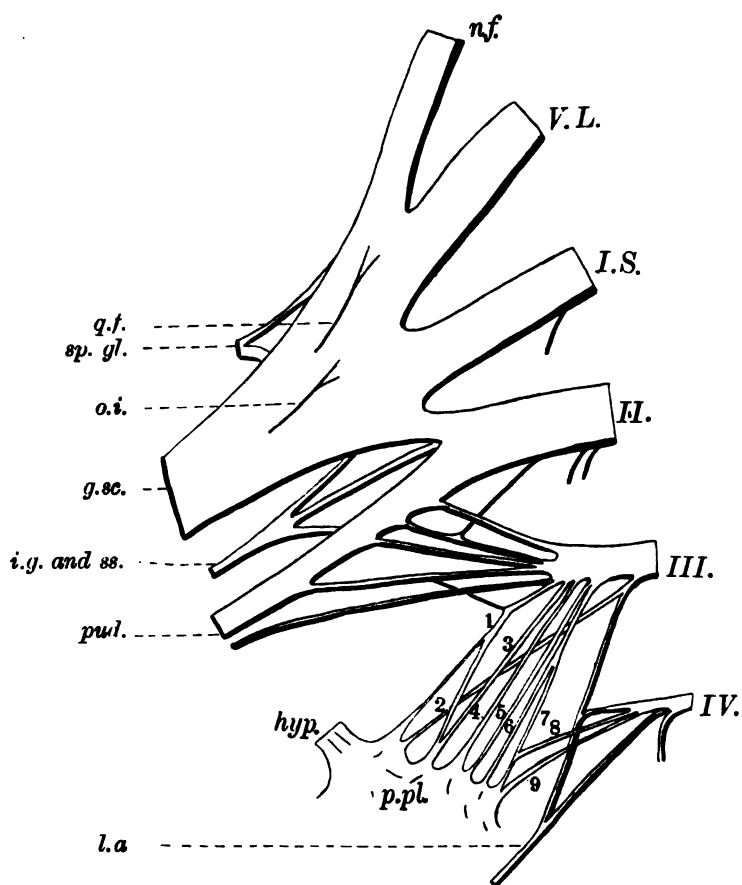


Fig. 11.—Subject, 'L,' right side. (♂ 55 c.m.)



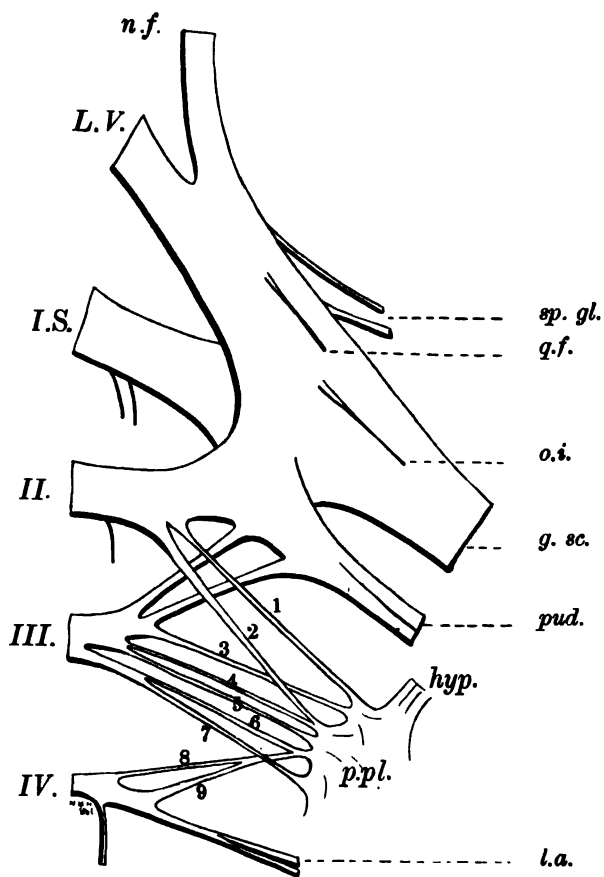


FIG. 12.—Subject, 'L,' left side. (♂ 55 c.m.)

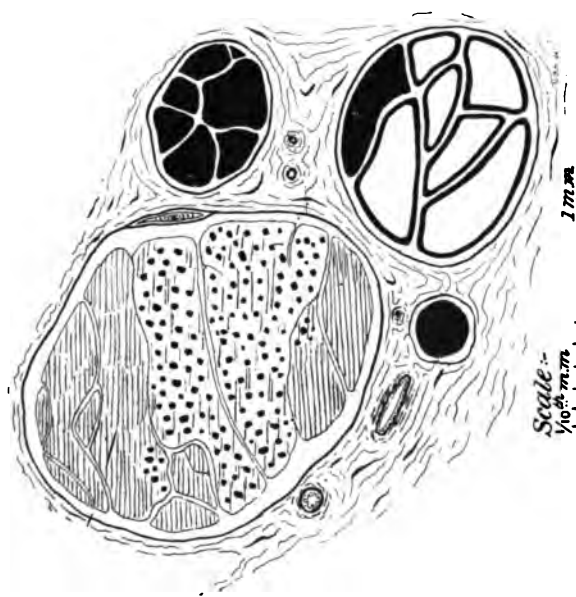


FIG. 13. — Transverse section of the IIIrd Sacral Nerve ('H' right), taken immediately distal to the bulk of the Ganglion. (Drawn with Camera Lucida.)

Anterior Root :—Fasciculi blackened = Somatic efferent fibres (coarse).

Do. darkly outlined = Splanchnic fibres (fine).

Posterior Root :—Horizontal shading = Nerve fibres.

Dots = Ganglion cells.

Journal of Anatomy and Physiology.

A SYSTEM OF PERIVASCULAR LYMPHATIC CYLINDERS AND CAPSULES IN THE UNITED AMNION-ALLANTOIS OF THE CHICK: MORPHOLOGY AND USE. By C. CREIGHTON, M.D. (PLATES XLI., XLII.)

THE following description relates to a peculiar system of lymphatic sheaths around certain tributary branches and capillary loops of the umbilical vein on the inner lamina of the chick's allantois, where it is adherent or fused with the amnion. They are not the ordinary lymphatics of the allantois, whether of the outer or the inner lamina, as described by A. Budge and Fülleborn, but a special system of ensheathing cylinders and capsules at certain spots, which have a special mode of development, and serve a special temporary use. My investigation of them has arisen as a subsidiary point in a morphological research upon glycogen, of which Part II. relates to the glycogen of snails and slugs. In correspondence with my conclusion for mammalian embryos, already published in Part I. (London, 1896), that animal starch is a parenchymatous medium in some way complementary to the blood, I conclude, upon evidence which I shall publish shortly, that the animal starch of these molluscs has the same relation to their white blood that the lymph of vertebrates has to their red blood. The only part of that homology which I require to mention here is the thick sheath of large glycogen-bearing cells around the walls of arteries. Morphologically these perivascular cellular sheaths would correspond, in my view, with the lymphatic cylinders which invest the blood-vessels (especially the arteries) of cold-blooded vertebrates, and are found also in some situations in the higher vertebrates. The question arose,

whether any instance could be found of an actual adaptation of perivascular cellular sheaths to become lymphatic cylinders? Within the molluscan division itself, it has been thought probable, both by Erdl and Leydig, that the extensive sheath of loose connective tissue round the arteries of some of the Cephalopoda, which replaces the sheath of large clear cells in the Gastropoda, was a lymphatic sheath, comparable to that of cold-blooded vertebrates. Leaving that doubtful case aside, I was led to study the yolk-sac of the chick, which has around its blood-vessels sheaths of large cells that have been compared by Cl. Bernard to the glycogen-bearing sheaths of the snail's arteries. I did not, however, find any adaptation of the perivascular sheaths of the yolk-sac to become actual lymphatic cylinders. Whatever changes the cells underwent in the way of vesiculation, elongation, and investment by mesoblast, they were never fused to make a tube. But at a certain part of the allantois there were perivascular cellular sheaths, constructed on the same lines as those of the yolk-sac, which did actually develop into a remarkable system of lymphatic cylinders and capsules.

Lymphatic cylinders and capsules of the allantois.—A general view of them is shown in fig. 1, drawn under a magnifying power of about 20 diameters, and standing for an area of the specimen about $\frac{1}{4}$ in. \times $\frac{3}{8}$ in. The structures, which are of temporary duration, are at their most perfect state in chicks of ten, eleven and twelve days. They do not exist over the whole of the inner lamina of the allantois (on its outer lamina they do not occur at all), but only at certain areas near the limit of union with amnion round the cup-like thick edge of the lobes of yolk-sac in fixed eggs: these areas, which seldom exceed half a square inch, may be discovered by the naked eye from their shagreen-like or grained surface, by which they are mapped out definitely from the rest of the membranes.¹ Cut out and stained upon a slide with picro-carmin, the grained

¹ F. Fülleborn, in his *Beiträge zur Entwicklung der Allantois der Vögel* (Inaug. Diss., Berlin, 1895), p. 27, note, mentions "ein eigenartiges, verwaschen-fleckiges Aussehen" of the united amnion-allantois, as well as of limited spots of the internal allantois where it is not joined to the amnion, which he accounts for by the fact "dass die Kerne des inneren Blattes der Allantois an einzelnen Stellen dichter stehen wie an anderen."

patch of membrane is found to present a singular and beautiful appearance. Referring to fig. 1, it will be seen that it is the vascular territory of a considerable tributary of the umbilical vein which joins the main trunk not far from the umbilicus; the blood-vessels are wholly venous and capillary; the medium-sized vessels form loops to such an extent as to make a kind of plexus. Within certain of these loops on the right side and upper half of the figure the capillaries are most abundant, corresponding with the end-territory of the principal vessel. The blood-discs within the vessels take the carmine colour vividly, so that the effect is that of a very perfect injection, in which the structural features are not obscured. Around the whole of this vascular system,—main stem, lateral branches with loops, and capillaries,—there are wide lymphatic sheaths. In the low-power figure they are drawn as if empty, but in reality they are filled by a nucleated pulpy tissue, as in the high-power drawing, fig. 2. The sheaths around the central venous stem and the branches are continuous cylinders, which keep a somewhat uniform width throughout the whole system, so that they are relatively more capacious round the smaller veins than round the larger. In the proper capillary territories the sheaths have the very peculiar form of spherical or oval or oblong saccules or capsules, which occur at intervals, usually at the confluence of two or more capillary streams. The whole field within one of the venous loops may be packed close with these capillary saccules or capsules. It is to them that the grained or shagreen-like appearance of the surface is due. A transition form from the round or oval capsules to the long continuous stretches of cylinder is seen upon certain capillaries at the margin of the capillary region towards the lower side of the figure. The cylindrical sheath is constricted at intervals, so as to be made into two or three or more oblong closed saccules.

What remains to be said of the structure may be taken in connection with fig. 2, which is a high-power drawing of a single loop situated at the lower right side of fig. 1. The focus is adjusted to show the inner or entodermal side of the allantois. At the depth of the specimen there is a strong sheet of plain muscular fibres, disposed for the most part crosswise to the run of the vessels, consisting mainly of the adherent amnion, but of

some allantoic muscularis united therewith. The lymphatic sheaths stand widely open, with their walls as if fixed. They are never collapsed or puckered, so that they are easily seen without injection. The wall of the sheath is formed of flattened cell-plates, seen edgewise as dark lines. The wide space between the wall and the vessel in the axis is filled by a cellular pulp, of which the variously-shaped nuclei are more obvious than the delicate circular outlines or branching processes of the protoplasm. This description of walls and interior pulp applies equally to the shut-off capsules and saccules of the capillaries.

Development of the lymphatic cylinders and capsules.—Fig. 3, drawn to the same scale as fig. 1 (20 diam.), shows that state of the entodermal surface of the allantois and its vessels which immediately precedes the formation of lymphatic sheaths round the latter. The loops of vessels are the ordinary wide capillary meshes which are distinctive of the inner lamina of the allantois, contrasting with the much closer meshes of its outer lamina. The vessels are now become tortuous, and they run in the axis of thick cellular sheaths. Moreover, the whole field of entoderm enclosed within a mesh is beset close by conical elevations or papillæ, with broad bases and rounded or flattened heads. The cellular cords or rolls around the vessels belong to the same system as the papillæ, being such of the latter as are seated along the sides of the tortuous vessels, and have become more or less fused into a corkscrew sheath; some of the papillæ within the mesh may in like manner become fused into elongated ridges. At this stage of the development the only blood-vessels that are to be seen are the original wide-meshed capillary loops. The allantois over the areas that are thus papillated or mammillated is a membrane of considerable thickness. It has an outer wall of plain muscular fibres, which mostly run in the longitudinal course of the vessels, but have also a warp-and-woof texture at some places. Fig. 4 shows, under a high power, the appearance of the allantois with the muscular coat in focus, the broad bases of the entodermal papillæ being seen dimly through the sheet of muscle. When the entodermal surface is brought into focus, the flattened papillæ, by which it is beset closely, look to be made up wholly of a heap of epithelial

cells, which are nearly all nucleus or have little protoplasm. External to the muscular layer there is a delicate stratum of branched connective-tissue cells, set in a granular ground-substance.

The systems of perivascular lymphatic cylinders and capsules are found at certain areas of the union or fusion between amnion and allantois. Occasionally a similar patch is found on the allantois beyond the union, marked by great thickness of the muscularis with stellate ridges, the relation of the sheaths to entodermal papillæ being the same. The union of amnion with allantois determines the farthest development of the lymphatic sheaths of the umbilical vessels. It is not, however, a simple flat sheet of amnion that becomes united with the adjoining muscularis of the allantois, but a field of amnion thrown into the peculiar ridged and furrowed state shown in fig. 5. This is a structural, not a mechanical puckering, and it is confined to certain areas which shade into ordinary smooth amnion. It may be seen in the funnel-shaped part of the amniotic sac next to the umbilicus as early as the chick of eight days; accordingly, it begins almost as soon as the development of the muscular fibres in the membrane, and it may be said to depend upon the shooting-out of those fibres along different planes or in different directions. The result is a series of stellate figures of ridge and furrow, the radiations of each figure proceeding from a narrow central plateau, as if a core or centre of dense muscularis.

I find this puckering of the amnion (which has been noticed also by Fülleborn, but without further remark) usually, it is not easy to say invariably, near to the line of fusion between that membrane and the allantois; so that it may be said to be an antecedent of the union on the side of the amnion. The puckered amnion and the mammillated allantois lie in juxtaposition for a certain space, as if ready to become united closely. In the first stage of this union, the state of things is so complicated that it is hardly possible to make a drawing of it. No vessel of the allantois runs any distance without turning upon itself, and presenting a knee or knuckle which corresponds with some fold of amnion; so that the whole vascular and muscular fields appear to be in an inextricable coil. To get

the simple appearance of united amnion and allantois as in fig. 1, with the veins, venous loops, and capillaries all extended on a flat surface, one must assume that the puckerings of the amnion had become effaced, and the tortuous vessels straightened as the sac became extended with the growth of the embryo. I find this ridged and furrowed union of amnion and allantois, with some appearance of sheaths round the blood-vessels, to exist close to the umbilicus in the chick of eight days; on the other hand, in chicks of eleven and twelve days there are still areas of puckered amnion and mammillated allantois which have not interlocked, but are only in juxtaposition; so that the progressive spread of the union upon the yolk-sac may proceed on the same plan for a day or two longer, or until the papillæ atrophy.

The changes which take place after union with the amnion, so that the condition of the allantois which is drawn in fig. 3 shall have become the condition drawn in fig. 1, are intelligible enough. The solid cords around the vessels become occupied in their interior by pulpy tissue, and at the same time distended thereby, so that a true perivascular lymphatic cylinder results. In like manner, the broad-based papillæ on the entodermal surface become filled with the same kind of pulpy tissue, whereby they are changed into the lymphatic capsules of fig. 1. The situation of these capsules at the confluence of two or more capillary streams is easily explained. A great development of new capillaries takes place within the wide meshes of the original capillary loops, where the allantois adheres to the amnion, as well as where it adheres to the serosa to form the albumen sac (Fülleborn). Of this new capillary formation nothing can be seen in the papillated state of the allantois, the new vascularisation taking place under cover of the somewhat thick papillæ; but when the papillæ either wither or become lymphatic capsules with an open pulpy interior, the existence of the capillaries is revealed, the capsule being situated very significantly at the nodal point of several of them.

The exact histology of the conversion into sheaths filled by pulpy tissue does not appear to me to present any difficulty. The thickened entoderm of the allantois makes up undoubtedly the most of the substance of the perivascular cords and broad-based papillæ, if it does not make up the whole. It is hardly

possible to examine these structures except in the face view, wherein we seem to find a heap of cells of only one kind, namely, the entodermal: they are mainly nucleus, with little protoplasm, and with the limits of adjoining cells ill defined, contrasting in these respects with the epithelium of the pear-shaped allantoic vesicle of four days (which has also a highly mitotic state of its nuclei), as well as with the somewhat obvious mosaic pattern of flat epithelium at other stages or situations. The flat cell-plates which form the wall of the lymphatic sheath (fig. 2) are the surface layer of entoderm; and it does not appear that the interior pulp could have sprung from any other kind of element than the lower layers of the thickened entoderm. There is, at all events, no theoretical objection to a mucous pulp springing from epithelium; for the pulp of the enamel organ, which is the most exquisite type of such a tissue in the body, arises from a mass of epithelial cells, as Huxley originally maintained at a time when it was held that the branching cells of a mucous 'connective tissue' could spring only from mesoblast. As to the matter of fact in this case, what one sees in the early stage of the formation of the pulpy tissue is an occasional very large vesiculated cell, with one or more nuclei on its periphery, such as is drawn in fig. 4, *a*, in the base of one of the papillæ. There does not appear to be any class of elements other than the epithelial which furnish such vesiculations: they occur in the midst of the heap, as if some of the epithelial cells in the centre took on that action, whilst others ranged themselves round the periphery. The most obvious mesodermal elements underlying the papillæ are, in the first place, the considerable layer of muscular fibres, and, outside that, a very distinctive and beautiful layer of somewhat cubical connective-tissue cells, with large nuclei, and with protoplasmic processes, which are set at wide regular intervals in a granular ground substance. These, it is conceivable, might be a source of the pulp; but they do not, in matter of fact, appear to penetrate the muscular coat, so as to reach the bases or interiors of the papillæ. The origin of the pulp is, however, an open question.¹

¹ Fulleborn, in his invaluable systematic description of the histology of the allantois of the bird's egg, has mentioned the papillary outgrowths on certain parts of the entoderm, and has associated such of them as are seated upon the walls of blood-vessels with a development of lymphatic cavities (p. 21). But he

Duration of the lymphatic cylinders and capsules.—This special perivascular apparatus is not only limited to certain parts of the inner lamina of the allantois, but it is also of limited duration. I have found the structures most perfect in chicks of eleven and twelve days; in ducklings of eighteen days, and in corresponding chicks of fourteen days, obvious traces of the capsules remain, while the cylinders, taking the carmine stain deeply, are found ensheathing long stretches of the larger vessels, and apparently forming the typical lymphatics of the area. In chicks of eighteen days, examined closely after fixing in Kleinenberg's fluid, I have failed to find any traces of either. It is known from the observations of H. Virchow and Fülleborn that the original union of the amnion with the allantois is so far dissolved in the latter stage of incubation that the muscularis of both membranes becomes greatly thinned, while Fülleborn includes with these retrogressive changes the disappearance of the ordinary pairs of lymphatic vessels running by the sides of the umbilical arteries and veins. The disappearance of the special shagreen-like areas of the amnion-allantois union would be but a part, therefore, of a series of retrogressive changes. As early as chicks of twelve days, I have found one side of the special area in a state of retrogression, while the structures in the other side of it remain in full vigour. The contrast between the two parts is brought out

does not appear to have seen the remarkable system of detached capsules at all; and he touches so briefly upon the ensheathing lymphatics, as distinguished from the escorting pair of lymphatic vessels of his main systematic description (p. 20), that I should not have found his mention of the former intelligible had I not worked out the subject before. Referring to the spiral cellular cord around a blood-vessel, he says:—"Es entstehen nun in den lockeren Schleimgewebe dieses Gebildes Hohlräume, welche mit einem einfachen Endothel aus gekleidet sind, und welche sich von den Lymphgefäßen aus injiciren lassen" (p. 22). His other reference to lymphatic cylinders is as follows:—"Diese Lymphgefäße werden anfänglich nur durch vereinzelte, im weiteren Verlaufe durch immer zahlreichere Quer-Anastomosen mit einander verbunden, bis die Lymphgefäße beider Seiten endlich zu einem einzigen Lymph cylinder über den betreffenden Gefäße zusammen geflossen sind" (p. 20). Budge, in his text (1881, p. 625) and in his plates (1887, fig. 15), shows only a virtual ensheathing of the blood-vessel by a number of separate lymphatic vessels on its wall. The relation of the pair of escorting lymphatics to an actual ensheathing cylinder has been worked out minutely by Langer for the intestine and mesentery, testis, etc., of the frog. *Sitzungsber. d. Akad. des Wissensch. z. Wien*, liii. (1866), 1ste Abth.

very clearly by the picro-carmin staining: the carmine colour stops almost abruptly along a certain line (excepting in the ectodermal epithelial cells of the amnion, which stand out with unusual vividness), so that the blood corpuscles, which make a bright-red line within the lumen of one portion of a blood-vessel, are yellow in the rest of its course; the lymphatic sheaths also lose their structural character, and are seen, if seen at all, as mere tunnels in the tissue within which the blood-vessels lie. Lastly, the strong coat of muscular fibres of the amnion becomes cloudy, and the outline of individual fibres hardly recognisable. One effect of this melting away or effacement of structural characters in each of the membranes is to make the fusion between them more complete: while one can usually strip off the one membrane from the other by using some force with the forceps, the separation stops short along the line where the retrogressive changes, marked by yellowish colour and cloudy swelling, begin. This phase of complete fusion does not last long, for in the latter part of incubation the thick muscularis is absorbed.

Morphology of the perivascular cylinders and capsules.—The structural prototype of the cellular sheaths of vessels in a certain part of the allantois, and of the flattened papillæ of its entoderm which cover the development of new capillaries, is to be found in the yolk-sac; and the functional adaptation of these to become lymphatic cylinders and capsules after the amniotic sac has become adherent is to be found in the transference to the allantoic venous system of some part of the office of absorbing both yolk and albumen. The functional part of the problem, which is the more complicated part, is taken in the last section of the paper.

The blood-vessels which run on the interior of the chick's (or other bird's) yolk-sac afford one of the clearest instances in the animal kingdom of perivascular ensheathing by large cells. The distinction between the arteries and the veins in this system is not easy to make, and has only lately been determined by the laborious research of Popoff, who resorted to the method of tracing the arterial and venous branches to their respective omphalo-mesenteric stems. By far the larger part of the vascularity is found to consist of veins and capillary loops. For

my purpose, I may disregard the blood-vessels within the valvulæ or meridian folds, and take only the vessels which run in the flat intervals (the 'intermediate' vessels of Popoff's description) and the vessels upon the proximal pole of the sac. The large-celled sheath around one of these vessels and its cross branch is shown in fig. 6. The perivascular cells are the ordinary yolk-sac 'epithelium' (so called without prejudice to the theory of its parablasic origin), one layer deep, appearing in the side view as large columnar elements, in the face view (shown in the cross branch at a slightly different focus) as a polygonal nucleated mosaic: the nuclei, it will be observed in the side view, are at the attached ends of the cells, whereas in the corresponding sheaths of the arteries in snails, which are filled with glycogen, the nuclei are towards the free ends. Besides the long cylindrical sheaths of the vessels, there are found also certain detached spherical or oval heaps of epithelial cells at intervals upon the capillaries, more especially at the confluence of several. These are shown in fig. 7. The best instances of them are found towards the proximal pole, where the valvulæ come to an end in the flat membrane. They are said by H. Virchow to be placed upon the smaller vessels, 'perlschnurartig,' like pearls upon a string; but there are seldom more than two or three of them in a row. The epithelium of the flat surface around them (towards the proximal pole) is usually much thinned, the outlines of the cells being often mere crescentic lines, and the mesoblastic cells conspicuous through them. Still nearer to the proximal pole, the same type of nodular ensheathing structures is seen on a more general scale. It is the appearance drawn in fig. 8. Nearly all the visible blood-vessels lie to the right of the central tortuous vessel, which is ensheathed in the usual way; on the left of the figure the inner surface of the yolk-sac is studded over with numerous low papillæ or oblong ridges, in some of which a capillary is seen to run in the axis; at the upper part of the right-hand side the axial position of the capillary is more uniformly indicated.¹ If the drawing had been continued a little higher up it would

¹ Compare H. Virchow's account of the development of the primitive blood-vessels of the blastoderm under cover of, or in the bases of, folds or ridges of the entoderm (*l.c.*, 1891, fig. 24).

have shown the transition of these latter into a peculiar velvety island close to the actual pole (mentioned by H. Virchow), in which the papillæ are so close set as to resemble a patch of villi.

Although, in a morphological respect, these perivascular cellular sheaths of the vitelline system, both cylindrical and nodular, have a close resemblance to those above described for a certain part of the umbilical system, and may be regarded as a prototype of the latter, yet they do not anywhere become lymphatic sheaths, as those of the allantois do. The nearest approach to such an adaptation which I have found is the condition of the perivascular cells shown in figs. 9 and 10, drawn from vessels close to the proximal pole. In fig. 9 the cells are seen, where not overlaid by granular yolk, to be greatly elongated, and each occupied by several very large vacuoles. In other instances they look like oblong compartments of an actual sheath, having clear contents, and being drawn out to the length and joined end to end, as in a layer of vegetable parenchyma. In fig. 10, from a duckling of eighteen days, the cells are enormously enlarged, their protoplasm being occupied by many large vacuoles, and they are folded round the vein so as to make a spiral, which would be a continuous sheath if the adjoining walls of cells were absorbed. But the ensheathing cells of the vitelline system never lose their individuality,—so far not so, that the vesicular wall of each may even be overgrown by small mesoblastic cells. My view is, that the due development of the many cellular units of a sheath into a single lymphatic cylinder does not take place until a fresh start is made upon a new field, namely, upon the entoderm of the allantois, where the morphological plan of the yolk-sac sheaths is reproduced closely in all its details.¹ The probability, arising out of

¹ Giacomini (*l.c.*) describes, for a lizard-like reptile, *Seps chalcida*, which produces eight or ten young after a gestation of three months, an adaptation both of the allantois and of the yolk-sac, at the upper and lower poles of the egg respectively, to form each a kind of placenta on the same plan. The embryo within its amnion lies enclosed by the pair of hemispherical sacs, the circumferences of which touch each other. Outside both of them is the serosa, in this case a true chorion; its epiblast becomes thickened over each pole of the egg, uniting with the allantoic sac at the upper pole to form an allanto-chorion, with the yolk-sac at the lower pole to form an omphalo-chorion, while each of these combines with the mucosa of the oviduct to form a placenta. In this process both the allantois and the yolk-sac are described as producing the same kind of

the structural correspondence, as well as out of the general truth that the allantois is the successor, and to some extent the supplanter, of the yolk-sac, will be increased by considering, first, the inadequacy of the yolk-sac for absorption in the latter half of incubation; and secondly, certain facts as to a round-about way of absorption of albumen and yolk during the same period.

Difficulties in the absorption of yolk by the vitelline blood-vessels.—Controverting the erroneous statement that the yolk-sac undergoes retrogressive changes in its structure in the latter half of incubation, H. Virchow remarks:—"So far from there being degenerative changes in the yolk-sac during the second half of incubation, there is some reason for saying that the functions of the yolk-sac increase in the last days of incubation and the first days after hatching; for its task is seemingly more difficult, inasmuch as it is occupied with a tougher and progressively more inspissated yolk, not, as in the first half of the time, with a yolk that is largely diluted by the fluid of the perilecithal space" (*l.c.*, p. 252). If its functions increase in the latter half of incubation, and its task becomes more difficult, the structures of the yolk-sac ought to undergo some corresponding adaptation. But, apart from certain changes at the proximal pole, which will, I think, repay farther study, it does not appear that the yolk-sac is actually adapted to complete the absorption of its contents.¹ It is precisely a lymphatic system,

placental structure, namely, a system of ridges and close-set papillæ running in zigzag. As the microscopic anatomy is not given, I cannot say whether this is the same that I describe above for certain parts of the allantois and the yolk-sac of the chick. The upper or allantoic placenta of *Seps* is the larger and the more important physiologically, being a considerable elliptical patch, with many ridges and furrows running meridionally, while the corresponding structure formed by yolk-sac develops slowly, remains rudimentary, and shows only a few wrinkles, which have also the meridian plan.

¹ Haller took pains to ascertain the weights of the yolk-sac and its contents at various periods, which weights he gives; and his conclusion was expressed thus:—"I will make but one observation. The yolk diminishes hardly at all during the twenty-one days of incubation—one might even say that it increases. I have found it to weigh more after twenty-one or twenty-two days than at the first. But the liquid which it contains becomes more fluid and greenish" (p. 142). Since Haller's time the problem has hardly attracted notice until it was taken up by Professor Hans Virchow. His weights for the organ and contents at the time of entering the chick's belly are somewhat lower than Haller's; but he remarks that the sac at the end of incubation has its full size, measuring

intermediate between the yolk and the blood, which it may be said to want; and such a desideratum has been evidently in the minds of those who have investigated it recently. Thus, H. Virchow, in his account of the yolk-sac in the lizard (*l.c.*, 1892, p. 178), has suggested that certain narrow spaces or intervals at the attached ends of the enormous perivascular cells may be of the nature of lymph spaces; and Popoff, who did his work in the same laboratory, says: "Without farther investigation we are unable to decide whether the absorbed constituents of the yolk are brought to the body of the embryo by the veins or by lymphatic vessels hitherto undiscovered." My view of the matter is that the 'lymph' required in the later period for the absorption of yolk is obtained from the liquor amnii, partly by direct transudation from the amniotic sac, where it presses upon the proximal pole of the yolk-sac, partly by that system of lymphatic sheaths of the allantoic vessels, filled with lymph from the adherent amnion, to which yolk is brought from the yolk-sac by a roundabout way, along with much of the albumen from the albumen-sac.

I shall give the facts briefly under four heads:—(1) Absorption of albumen by the indirect way of the amniotic sac, as well as by the 'sac placentoidé'; (2) Mixture of yolk with albumen; (3) Albumen mixed with yolk in the interspaces of the united amnion and allantois; (4) Diverticulum of yolk-sac.

Absorption of albumen by way of the amnion.—It was known in 1722 to a French embryologist, Antoine Maitre-Jean, that the liquor amnii became more and more coagulable up to fourteen days of incubation, at which period the greater part of it became almost as hard by boiling as the white of a fresh egg. He found also in three eggs of fourteen days, less six hours, that the so-called plug of albumen at the lower pole was a sac, which in one case (figure given) was prolonged into a *queue* reaching to the lower edge of the amniotic sac (left or posterior side), in another case with flask-like neck stopping somewhat short of the amnion, and in the third case without

40 mm. in the meridian from pole to pole, and that the yolk within the sac is still several times the weight of the tissues of the sac in the first days after it enters the abdomen. According to his table, the great and rapid reduction takes place about the fourth day.

the *queue* altogether. It was through that neck, he guessed, that "beaucoup de parties glaireuses du blanc" passed into the amnion, but he could not find out precisely how the passage was effected, "quoique je me sois fort appliqué à chercher ce passage." The passage was discovered in 1893 by Hirota, in his research undertaken to show that the chick had the same sero-amniotic connection which Mitsukuri had discovered for the tortoise egg two years before: the band uniting the serosa and the amnion, or rather the plate of mesoblast which replaced the original ectodermal connection, was perforated by a number of larger or smaller openings situated at the attachment of the flask-shaped albumen-sac to the amnion, so that they could be seen from the inside of either sac. Through these openings the albumen passed from the albumen-sac into the liquor amnii, which became highly coagulable for several days after the date of the perforation (eleventh or twelfth day). This has been confirmed in a word by Fülleborn, who carries the process one step farther in pointing out that the liquor amnii is again free from albumen at nineteen days, and that such of the albumen as had passed into the amniotic sac "had been absorbed through the amnion." It is some special mechanism for the resorption here postulated that will seem necessary.

Mixture of yolk with albumen.—The hernia-like protrusion of a delicate saccule of yolk through the orifice or umbilicus of the albumen-sac, originally described by Duval, but doubted by H. Virchow, has been confirmed by Fülleborn as "a constant formation in eggs normally incubated." Much more easy to observe than the hernia-like sac is the presence of a certain amount of yellow yolk mixed with, or resting on the surface of, the white of the egg within the albumen-sac. I have seen this in ducks' eggs when not specially in search of it. H. Virchow has "several times found yolk in the albumen, outside the distal pole of the yolk-sac"; and Duval's language, in describing the difficulties of detecting the hernia-like bag of yolk, seems to me to imply that the white into which the bag protrudes was yellowed by escaped yolk,¹ as Mitsukuri found the albumen of

¹ "De plus, la faible masse d'albumine qui reste alors dans le sac placentaire a pris elle même une teinte jaunâtre, pale ou ambrée, de sorte qu'il est difficile de bien reconnaître par transparence le sac de l'ombilic ombilical et son contenu."

the tortoise egg to be yellowed. It is indeed difficult to assign any meaning to the membranous protrusion through the umbilicus of the yolk-sac, unless it be a mechanism for allowing yolk to pass into the albumen-sac.

Direct absorption from the albumen-sac.—The placental office which Duval assigned to the albumen-sac is not, of course, discredited by the discovery that much of the contents of that sac enters the liquor amnii through the sieve-like perforations of the sero-amniotic connection. The absorption of albumen by the epithelium of the serosa (which makes the inner lining of the albumen-sac) may be safely inferred from the peculiar opaque white appearance of the interiors of the cells, especially in the face view. But inasmuch as H. Virchow and Fülleborn (and, I may add, myself) have not seen the blood-vessels described by Duval in the axis of the villus-like growths of epithelium in the neighbourhood of the mesodermal ring, it does not appear that any of the absorbed albumen passes direct into the allantoic blood-circulation. The transmission at first is extra-vascular; and the question arises by what means the contents of the albumen-sac at length enter the blood. The allantois which unites with serosa to enclose the albumen is itself studded with papillæ, under which new vessels develop, and in which lymph channels arise, providing for local absorption. Moreover, flakes or lumps of albumen, mixed with yolk, both spheres and granules, are found in the interstices of, or between the layers of, the united amnion-allantois, or in a situation which would bring them into direct relation with the perivascular lymphatic cylinders and capsules, which are my special subject; the latter would be also the fitting means of absorbing from the amniotic sac the matters which had passed into it from the albumen-sac.

Albumen and yolk in the interspaces of the united amnion-allantois.—In fig. 2, showing the perivascular sheaths of the umbilical vessels under a high power, it will be seen that a layer of granular yolk adheres closely to them at certain places, and that several true yolk-spheres occur among the granules. The appearance has been included in the drawing, but it is probably due to some accidental smearing of the surface with yolk in preparing the parts; and I do not rely upon it

as evidence that the yolk really gets between the amnion and the allantois. But on examining afterwards various parts of the amnion-allantois union in three ducklings of eighteen days, I found that conclusion to be confirmed abundantly. In these specimens it is the albumen that is mostly in evidence, in the form of cracked, cake-like masses or lumps which take a certain degree of the carmine stain; but the admixture of yolk was shown conclusively by the presence of not infrequent yolk-spheres. The intermediate position of these matters was beyond doubt. Thus, in one specimen, the highly muscular amnion was retracted somewhat from the allantois along the cut edge, and a lump of albumen projected half way from under the amnion, but rested wholly on the allantois. The presence of yolk as well as albumen between the membranes is so clear in these ducklings of eighteen days that I cannot suppose there is any possible mistake. In one special case I found a large collection of pale yellow substance, containing many yolk-spheres, within a distinct allantoic sac, which was bounded on one side by the wall of the albumen-sac, and had the main trunk of the umbilical vein encircling it on other sides, so that it corresponded exactly in its relations to the fold of allantois which Hirota has described and figured under the name of the 'allantoic septum.' The amnion did not appear to give a covering to the encapsuled space; but the capillaries in its wall had the striking parallel course which leads up to the intimate union of the allantois with the amnion (*cf.* Fülleborn), and there was in the specimen a flap of pure amnion, with its attachment along the upper limit of the encapsuled space. Also the so-called 'mesenteries' of the allantois, at the transition from the inner to the outer or shell-lamina of that membrane (for the nature and origin of which I refer to the papers of Mitsukuri and Hirota), appear to me to have albumen in their folds, inasmuch as they become to the naked eye white and stiff after absolute alcohol.

It may be concluded that albumen from the albumen-sac, with some admixture of yolk, has in the second half of incubation an extravascular transit, that it enters the interstices of the amnion-allantois union, and that the lymphatic cylinders and capsules around the capillaries and veins of that union (as well

as of the albumen-sac) are a special mechanism by which the substances are at length taken into the blood. That part of the albumen which passes into the liquor amnii would also reach the blood at length by the same mechanism.

The diverticulum of the yolk-sac.—This structure was seen by H. Virchow in a chick of seventeen days, arising not far from the proximal pole as a funnel-shaped tube three-eighths of an inch long, filled with yolk, the neck of the funnel ending in a blind sac upon the amnion. I have two preparations of it, one in a chick of twelve days, the other in a duckling of eighteen days. Both agree on the whole with H. Virchow's data, but that in the chick is much larger than the other, the quantity of yellow in the funnel being great enough to attract notice at once. The wall of the tube is thin, and does not appear to me to have any yolk-sac epithelium.

The research of Fülleborn has given special interest to this curious appendage, inasmuch as he finds it constant in the second half of incubation in all the species of birds examined by him—inserted between the inner lamina of the allantois and the amnion in an interspace near the beginning of the umbilical vein and right umbilical artery where the union of the two membranes is wanting. Perhaps this does not mean that it has constant characters in all the individuals of a species. I have found its place taken exactly in one instance by a flat band, expanded both at the vitelline and amniotic end, which is precisely the vitello-amniotic ligament of Pander's figure (fig. 5, pl. ix. Op. 1817), and I believe that it is the same structure which is still farther reduced to the fine round vitello-amniotic filament, which H. Virchow has seen two or three times, and I have seen once. But Fülleborn's statement cannot fail to raise the question whether we have not here to do with a regular means of conducting yolk from the yolk-sac to the interspace between the amnion and allantois, in some such way as the *queue* of the albumen-sac—itself a variable thing—is a means of conducting albumen.

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EXPLANATION OF PLATES.

PLATE XLI.

Fig. 1. A low-power view ($\times 20$) of a territory of the umbilical vein near its termination, from a chick of twelve days. Lymphatic cylinders around the veins; round or oval capsules on the capillaries, usually at the confluence of two or more. The membrane consists of fused amnion and allantois.

Fig. 2. High-power view of a small portion of the same, from right lower margin of fig. 1. $\times 195$ diam. The lymphatic cylinders filled by reticular pulp with crescentic or other forms of nuclei. The blood-vessels dimly seen in the axis of the cylinders. Masses of yolk, with some yolk-spheres, adhering to the outside of the cylinders. The allantois is here seen from the entodermal surface. The field is crossed transversely at a deeper focus by the strong sheet of plain muscular fibre belonging to the amnion.

Fig.

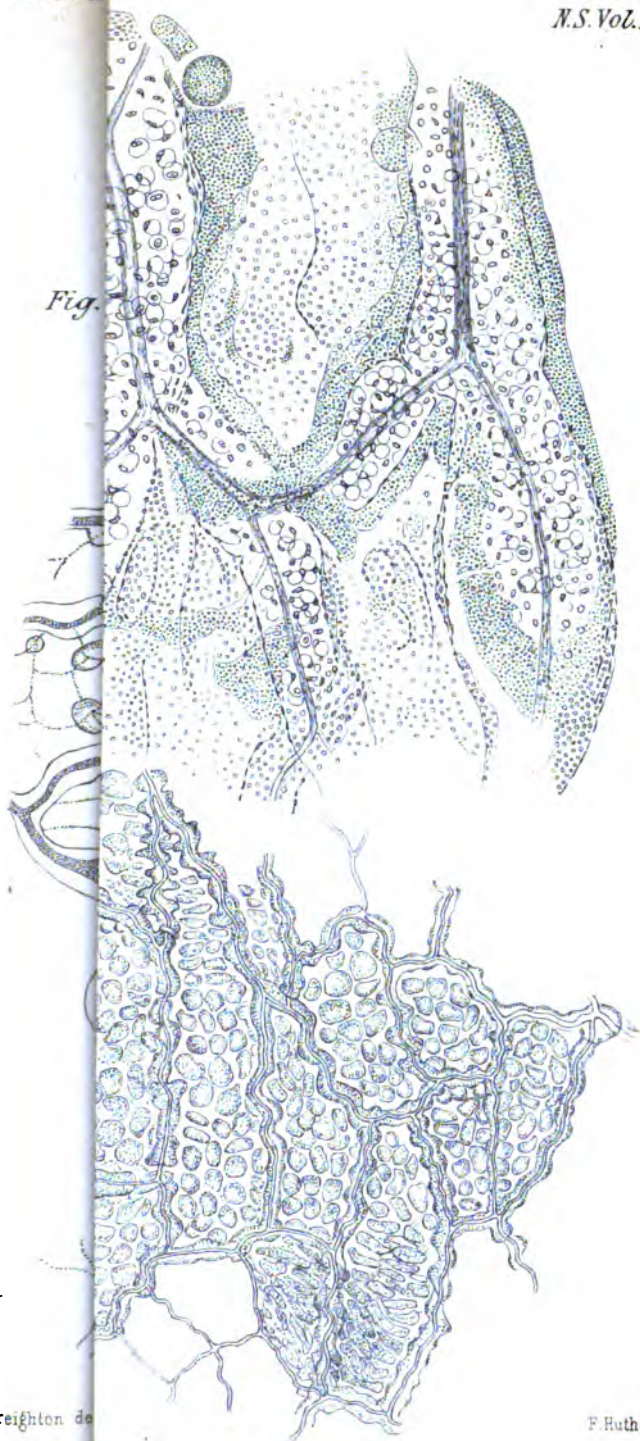


Fig. 6.

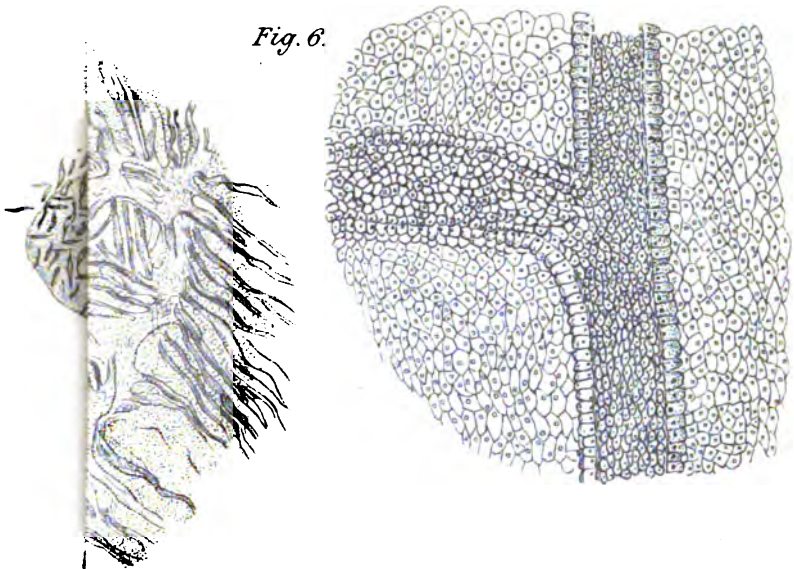


Fig. 7.

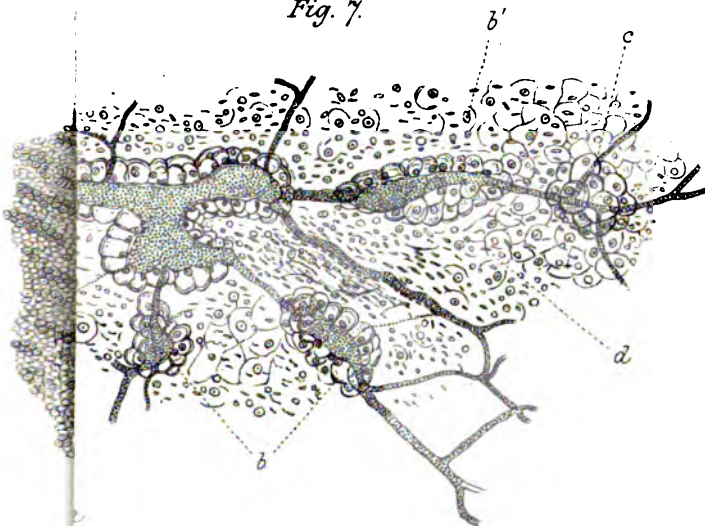


Fig. 10.



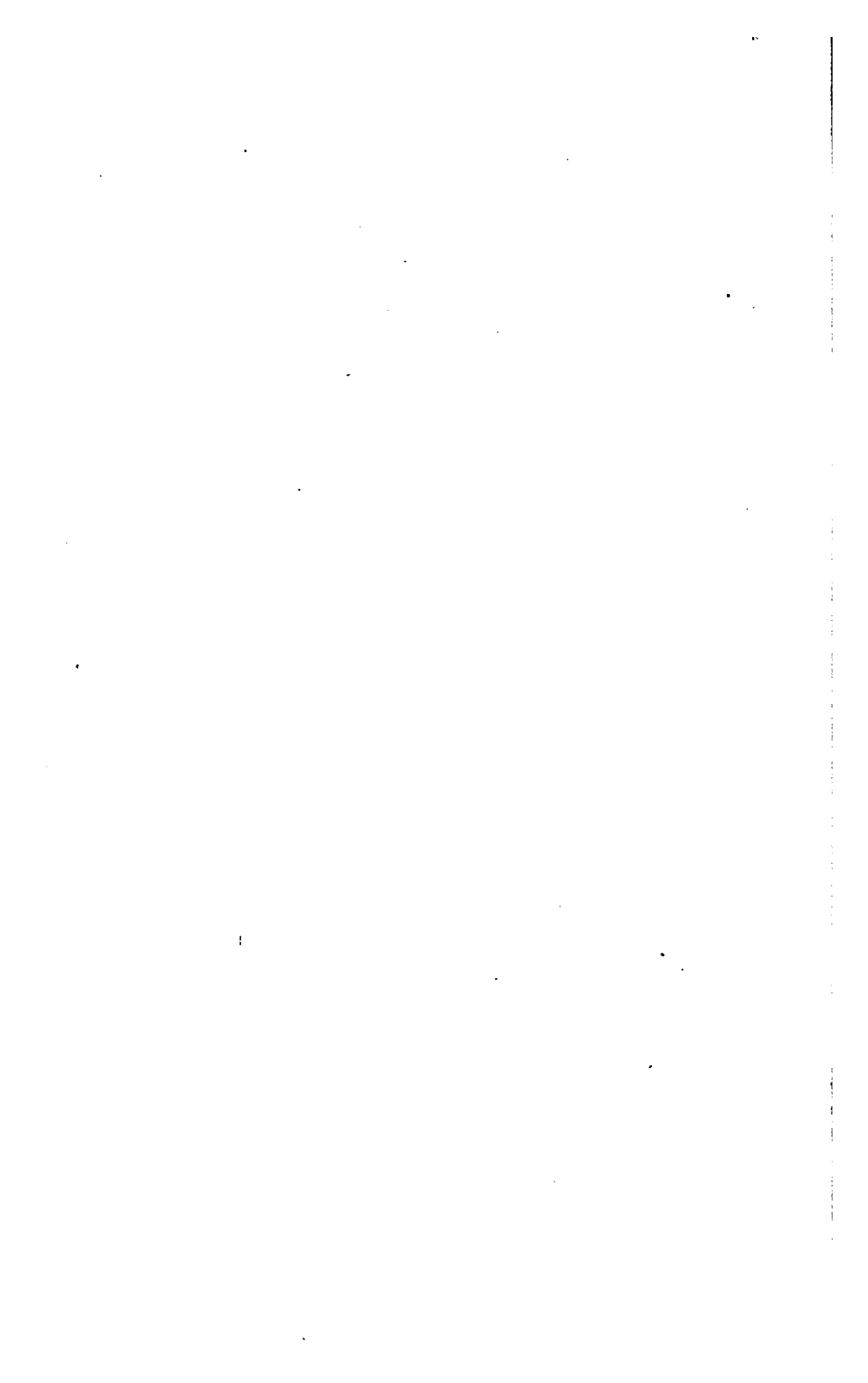


Fig. 3. Chick of twelve days. Low-power view ($\times 20$) of a field of allantois beyond the union with the amnion. Seen from the entodermal side. The wide-meshed capillaries are mostly tortuous, and are invested by solid sheaths of cells coiled round them in corkscrew fashion. The intervals of the meshes are closely studded with flattened papillæ of the entoderm. There is a muscular coat beneath, shown in fig. 4.

PLATE XLII.

Fig. 4. Muscular coat of allantois of a chick of twelve days. $\times 450$. The shaded outlines are the bases of the flattened papillæ on the farther or entodermal side.

Fig. 5. Amnion beyond the line of junction with the allantois. $\times 20$. Chick of twelve days. Structural wrinkling. Formation of ridges and valleys radiating from central plateaus of dense muscular fibre.

Fig. 6. Vessels on the wall of the yolk-sac towards the proximal pole. \times about 80 diam. Chick of eleven days. Vein and cross branch focussed to show the face view of the perivascular cubical epithelium; the mosaic-like outlines of the cells are brought out well by the picro-carmine staining.

Fig. 7. Spherical and oval clusters of epithelial perivascular cells of the yolk-sac (chick, eleven days) outlying from the ends of the valvulæ. *a*, the proximal end of one of the valvulæ; *b*, *b'*, outlying clusters of epithelium with a vascular axis; *c*, a less prominent heap, covering the junction of several capillaries. \times about 130 diam.

Fig. 8. Wall of the yolk-sac from near the proximal pole in a duckling of eighteen days. $\times 20$ diam. The field to the right is richly vascular; on the left of the central tortuous vein the vascularity is hidden beneath numerous eminences or flattened papillæ of the epithelial surface; but at the top and bottom of the left-hand field it is seen that the clusters of epithelium have a capillary in their axis, as on the right-hand side in general.

Fig. 9. Portion of vessel, probably artery, from yolk-sac of chick of eleven days, close to the proximal pole. *a*, large perivascular cell with two large and one small vacuole occupying its interior; *b*, three greatly enlarged cells reticulated in the interior; *c*, mass of yolk adhering to the perivascular epithelium, with small nuclei at intervals, which take the carmine staining deeply (Hartn. vii. 2, tube in).

Fig. 10. Vein with large yolk-cells twined round it, from proximal field of the yolk-sac, in a duckling of eighteen days. \times about 200.

THE MORPHOLOGICAL SIGNIFICANCE OF CERTAIN
FISSURES IN THE HUMAN LIVER.¹ By Professor
ARTHUR THOMSON, Oxford.

THE frequent presence of irregular clefts or fissures on the under surface of the human liver is a matter of everyday experience. Occurring as they mostly do on the inferior aspect of the right lobe, in front of the caudate lobe, and to the right of the gall-bladder, their scattered and varied positions, at first sight, fail to suggest any uniformity in their arrangement. Another situation in which these anomalous fissures are by no means uncommon is in the proximity of the right anterior border: here they are met with either cleaving the margin of the liver in line with the fossa for the gall-bladder, or, it may be, cutting through the anterior edge of the right lobe at a variable distance to the right of the gall-bladder. The constant recurrence of these fissures in a number of livers suggested to me the advisability of studying the foetal conditions of that organ.

With this object in view, I obtained a number of foetal livers varying in age from two months up to full term, and it is the result of this enquiry which I now desire to lay before the

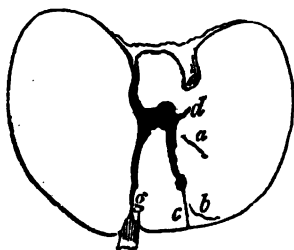


FIG. 1.—Human foetus (enlarged).

Society. The earliest specimen at my disposal was one measuring 13 mm. from side to side, and 11 mm. from before backwards (see fig. 1); in this, the most striking feature was the manner in which the gall-bladder was disposed. As will be seen from an examination of the figure, the fundus of the gall-bladder,

¹ Read before the Anatomical Society of Great Britain and Ireland.

which reached a point about midway between the hilum and the anterior border, was lying uncovered in a sagittal fissure which reached the anterior margin between the fundus of the gall-bladder and the hilum of the liver. The body of the gall-bladder was almost completely concealed by the overlapping of the edges of the fissure in which it lay, thus suggesting the impression that the gall-bladder in the course of its development at first lay deeply in the substance of the liver, and reached the under surface at some considerable distance in front of the hilum. In this early specimen the anterior edge of the caudate lobe was separated from the rest of the liver by a narrow cleft (*d*), and there were indications of an oblique fissure (*a*) crossing the under surface of the right lobe in a line from near the right extremity of the hilum towards the right antero-lateral edge.

Fig. 2 represents the appearance displayed at a later stage. It measured 25 mm. by 20 mm., and shows a corresponding arrangement of the gall-bladder and the fissure in which it is lodged, differing, however, from fig. 1 in that the anterior extremity of the fissure (*b*), in place of passing directly towards

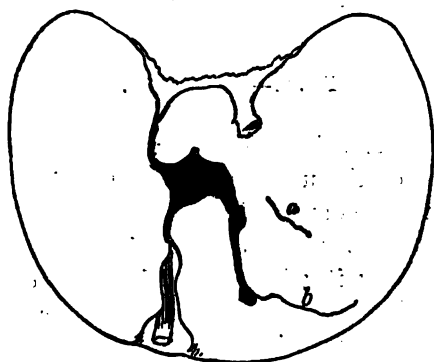


FIG. 2.—Human fetus.

the anterior edge, curved forwards and to the right, so as to lie within the anterior border of the under surface of the right lobe. In this specimen the caudate lobe, though prominent, was not separated from the rest of the liver substance in front by a fissure, though a distinct cleft, similar in position and direction to that represented in fig. 1, *a*, was observed (*a*).

Fig. 3, which represents the appearance of a slightly larger specimen, measuring 28 mm. by 21 mm., displays the fissure (*c*) for the gall-bladder passing directly forwards to the anterior edge. At the same time, the body of the gall-bladder is much more exposed whilst leading from the right side of the fissure in which it is lodged, in line with the anterior lip of the hilum, there is a short cleft (*a*), which in its position and direction appears to fall in line with the fissures marked *a* in figs. 1 and 2. In this example the caudate lobe is separated in front from

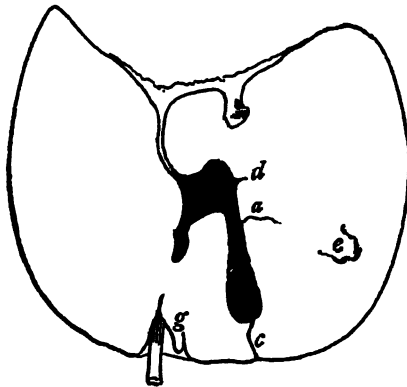


FIG. 3.—Human foetus.

the rest of the liver substance by a very short fissure (*d*). In addition, placed on the under surface of the right lobe, near its antero-lateral, rounded angle, there is a small semilunar cleft (*e*). It is not necessary to enter into a detailed description of each specimen examined; it will be sufficient for our purpose to figure those which present any unusual features, or those which by the arrangement of their parts help to elucidate the grouping of the fissures. Fig. 4 represents the appearance of a liver about the eighth month, measuring 9 cm. wide and 5 cm. in the sagittal plane. Here the fissure marked *a* in figs. 1, 2, and 3 is definite and well marked, whilst the fissure for the gall-bladder (*c*) is carried forward to the anterior border. In this case the fissure marked *e* in fig. 3 is also present, its form and position being remarkably like that shown in the previous figure. Fig. 5 displays a somewhat different arrangement; the specimen

measures 75 mm. across and 36 mm. in the sagittal plane, probably from a foetus about the seventh month. Here fissure *a*,

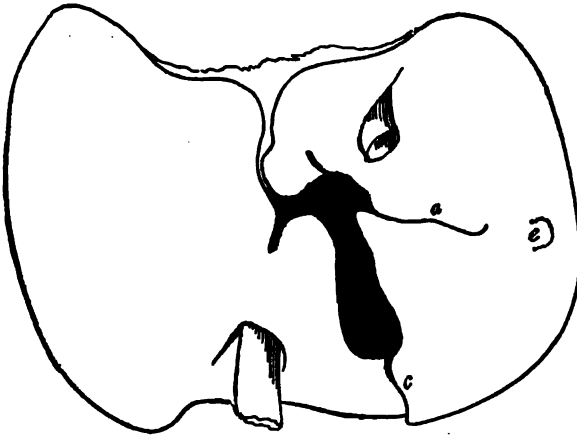


FIG. 4.—Human foetus.

figs. 1, 2, 3, and 4, is well seen. Fissure *b*, which curves to the right from the right side of the fossa for the gall-bladder (see also *b*, fig. 2), is also present; whilst fissure *c*, figs. 1, 3, and 4, is

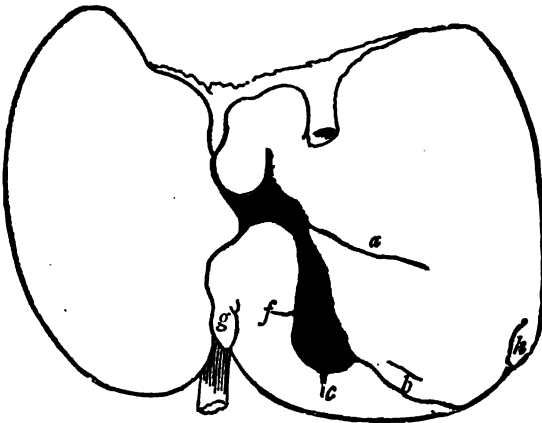


FIG. 5.—Human foetus.

represented by a cleft (*c*, fig. 5), which leads forwards from the fossa from the gall-bladder, but does not reach the anterior border. In this specimen an additional fissure marked *f* is

seen; it passes from the left edge of the fossa for the gall-bladder for a short distance towards the umbilical fissure. Towards the right antero-lateral angle, the border is also notched so as to form a small projecting lobule (*h*, fig. 5).

Fig. 6, the liver of a seventh-month foetus, measuring 78 mm. by 35 mm., is also interesting, as here is represented a condition in which the caudate lobe is defined in front from the rest of the right lobe by a fissure distinct from that represented at *a* in the previous figures. In fig. 6 this fissure is marked *d*, and co-

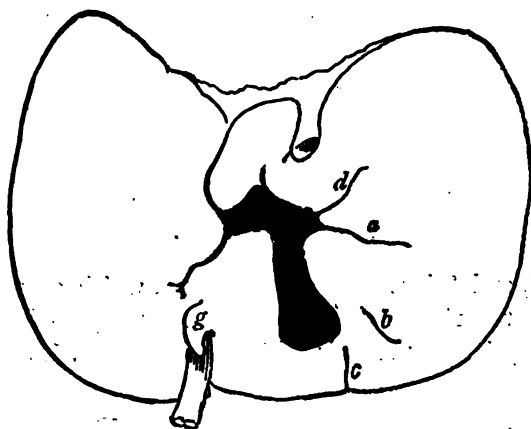


FIG. 6.—Human foetus.

exists with *a* which occurs in the same specimen, thus clearly demonstrating the independent character of the two clefts; in addition, there are clear indications of the fissures already referred to in previous specimens figured, viz., those marked *b* and *c*. That this arrangement is not singular is proved by the occurrence of a similar disposition in two other specimens.

Fig. 7 represents the appearance of a liver measuring 43 mm. by 36 mm., and presumably about the fifth month; it is interesting as an example in which the fissure marked *d* in the previous figure separates the caudate lobe from the rest of the liver substance, so that it can be raised from, and is partly independent of, the under surface of the right lobe. The significance of this condition will be referred to more fully later, but here it may be noted as resembling closely the condition met with in the anthropoid apes.

From these different figures it is possible to construct a diagram which includes all the fissures met with in this enquiry;

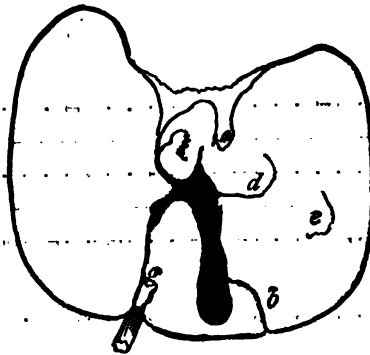


FIG. 7.—Human fetus.

this is represented in fig. 8, in which the fissures are lettered *a*, *b*, *c*, *d*, *e*, and *f*.

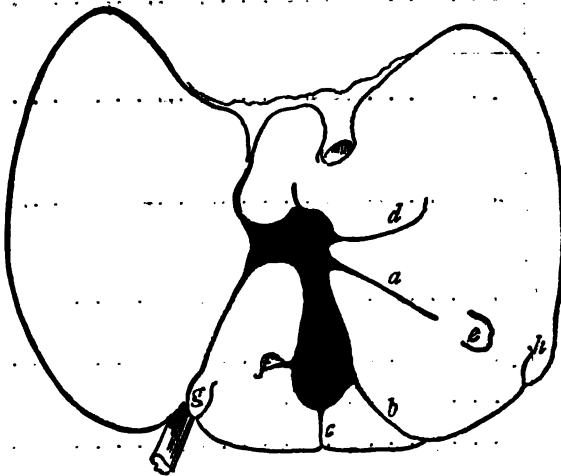


FIG. 8.—Composite figure of the arrangement of the fissures met with in the human foetal liver.

An analysis of the twenty-four foetal specimens examined is shown in the accompanying table.

FETAL LIVERS.	FIGURES.								Total Number of Figures present in each Specimen.	
	a.		b.		c.		d.	e.		f.
	Complete.	Partial.	Complete.	Partial.	Complete.	Partial.				
1. 6 to 7 weeks,	1	1	.	.	1	.	.	1	2	
2. About 2 months,	1	1	.	.	1	.	.	1	3	
3. " " "	.	.	1	.	.	.	1	.	2	
4. About 2nd to 3rd month,	.	.	.	.	.	.	1	1	2
5. " 3 months,	.	.	.	.	.	.	1	1	2
6. " 4 "	1	1	.	.	.	.	.	.	1
7. " 4 "	.	.	.	.	.	.	.	.	1
8. " 4 to 5 months,	1	1	.	.	.	.	.	.	1
9. " 5 months,	.	.	1	.	.	.	1	1	1	
10. " 5 "	1	.	1	1	1	.	1	.	3	
11. " 6 "	.	.	.	1	.	1	.	.	3	
12. " 6 "	1	.	.	.	.	.	.	1	1
13. " 6 "	1	.	.	.	.	.	.	.	2
14. " 7 "	1	.	1	.	1	.	1	.	3	
15. " 7 "	1	1	1	1	1	.	1	.	4	
16. " 7 to 8 months,	1	.	1	1	1	1	1	.	4	
17. " " "	1	.	1	1	.	1	1	1	4	
18. " 8 months,	.	1	.	1	.	1	.	.	4	
19. " 8 "	.	1	.	1	1	.	1	.	2	
20. " 8 "	.	1	.	1	1	.	1	.	4	
21. " 9 "	1	1	1	.	1	.	.	1	2	
22. " 9 "	1	.	.	.	1	.	.	.	3	
23. " 9 "	1	1	.	1	.	.	1	.	2	
24. " " "	.	1	.	.	.	.	1	.	2
Total, 24 specimens,	10	10	7	5	7	3	9	4		
	20		12		10		9	8		

ADULT LIVERS.					
1.	.	.	.	1	1
2.	.	.	.	1	1
3.	.	.	.	1	1
4.	.	.	.	1	1
5.	.	.	.	1	1
6.	.	.	.	1	1
7.	.	.	.	1	1
8.	.	.	.	1	1
9.	.	.	.	1	1
<hr/>					
CHILDREN.					
10. 6 years,	.	.	.	1	1
11. 7 years,	.	.	.	1	1
12. 6 years,	.	.	.	1	1
13. 1½ years,	.	.	.	1	1
Total, 12 specimens,	.	.	.	9	1
				{ 10 }	
				{ 8 }	
				{ 2 }	
				{ . }	
				{ . }	

Note.—The use of the terms 'partial' and 'complete' in regard to the fissures *a*, *b*, and *c* is intended to indicate a difference in their arrangement. In fissures *a* and *b*, where the clefts pass from the fossa for the gall-bladder, or from the hilum outwards and to the right, they are described as *complete*. When clefts occupying the line of these fissures occur independently on the under surface of the right lobe, and cut off by liver substance from either the hilum or the fossa for the gall-bladder, they are described as *partial*. Fissure *c* is *complete* when it extends from the hilum to the anterior edge; *partial* when it fails to reach the edge.

An examination of the above table brings out some interesting facts. Fissure *a*, in its partial or complete form, is the most common, occurring in about 83 per cent. of the specimens examined. Next in frequency is fissure *b*, with a percentage of 50. Fissure *c* appears in 41 per cent., fissure *d* in 37 per cent., whilst fissures *e* and *f* are represented by a percentage of 16 and 12 respectively. In every specimen examined one or more of these fissures occurred—1 fissure in 4 specimens, 2 in 10 specimens, 3 in 6 specimens, and 4 in 4 specimens. It is obvious, therefore, that these fissures have some significance, and their constant recurrence must in some way be accounted for.

Though the literature relating to the anthropoid apes is extensive, comparatively few descriptions of the liver are to be found. Thanks to the labours of Dr A. Keith, whose bibliography of the subject appears as the ninth volume of *Natural Science*, the examples described and figured can be easily referred to.

In his classical treatise, Tyson, in describing the liver of the chimpanzee, states that "it is not divided into lobes as in apes and monkeys, but entire as in man." "It had the same shape" (as in man).

Gratiolet¹ and Traill² refer to the greater depth of the fissures on its surface, but Flower³ gives a more detailed account. "In the chimpanzee," says this authority, "there are no traces of lateral fissures subdividing the right and left lobes. But what chiefly distinguishes the liver from that of man is the development of the ridge, which in him represents the caudate lobe, into a distinct or rather trihedral pointed body, connected at its base with the Spigelian lobe, but separated also by a fissure for nearly the whole of its length from the under surface of the right lobe. Its apex reaches to more than half way from the right end of the portal fissure to the right margin of the liver." Symington⁴ also refers to the large size of the caudate lobe as compared with man, but does not mention the fissure described by Flower.

¹ *Nouv. Arch. du. Mus. Nat. Hist.*, 1866, t. ii.

² *Mem. Wernerian Nat. Hist. Soc. Edinburgh*, 1817, vol. iii.

³ *Med. Times and Gazette*, 1872.

⁴ *Proc. Phys. Soc. Edinburgh*, 1890, vol. x.

In the gorilla the right and left lobes are deeply cleft so as to form four lobes in all, described as the right lateral, right central, left central, and left lateral. This arrangement is characteristic of the specimens described by Huxley,¹ Flower,² Chudzinski,³ and Deniker,⁴ but differs from that figured and described by Bischoff,⁵ in which the right lobe was alone subdivided. Deniker and Chudzinski both refer to the fact that in the specimens examined by them the caudate lobe is free, and not coalescent with the right lobe as in man.

Accounts differ somewhat as to the configuration of the liver in the orang. Bischoff⁶ describes the caudate lobe as widely connected with the right lobe, whilst Flower⁷ mentions the presence of a deep fissure running along its anterior edge, though in two specimens he states that it was arranged as in man. Chapman⁸ notes the absence of the quadrate lobe, and refers to the large size of the Spigelian lobe.

Most observers agree that the liver of the gibbons very closely resembles that of man. Kohlbrugge⁹ refers to the presence of the caudate lobe.

Flower,¹⁰ in summing up the characters of the liver in this group, says:—"Finally, the liver in all, except the gorilla, resembles that of man, and differs from that of all the lower apes in having no lateral fissures subdividing the right and left segment, but it differs from that of man in the possession of a small caudate lobe, which, however, has been found to be wanting in some specimens of oranges and gibbons. The abnormal form of the liver in the gorilla is one of the most interesting facts that has been brought to light by recent researches: it shows either that the modifications of the liver are not very characteristic in natural and related groups in animals, or that the gorilla ought not to occupy the position in the system which has hitherto been accorded to it."

¹ *Med. Times and Gazette*, 1864.

² *Med. Times and Gazette*, 1872.

³ *Bull. Soc. Anth. Paris*, ser. 3, t. vii.

⁴ *Archiv. Zool. Experiment.*, 1885, ser. 2, t. iii.

⁵ *Abh. Math. Phys. Cl. Akad. Wiss. München*, 1880, Abth. iii.

⁶ *Abh. Math. Phys. Cl. Akad. Wiss. München*, 1870, Bd. x., Abth. iii.

⁷ *Med. Times and Gazette*, 1872.

⁸ *Proc. Acad. Nat. Sc. Philadelphia*, 1880.

⁹ *Max Weber's Zool. Ergebnisse*, Leiden, 1890, Bd. 1.

¹⁰ *Med. Times and Gazette*, 1872, p. 394.

The specimens figured by Flower in his lectures are no doubt those on exhibition in the Museum of the Royal College of Surgeons. I have not, therefore, included them among the specimens which I have personally described. Thanks to the kindness of the Curator, Professor Stewart, I had an opportunity of looking through the 'store' specimens. The liver of a young female chimpanzee was in such bad condition that little could be made out of it, but in four oranges the caudate lobe was free in two instances, separated from the right lobe in front by a deep fissure in one case, and fused with the surrounding liver substance, as in man, in the remaining specimen. In one example there was a faint indication of the fissure marked *a* in fig. 8, and in another specimen the right lobe was deeply cleft

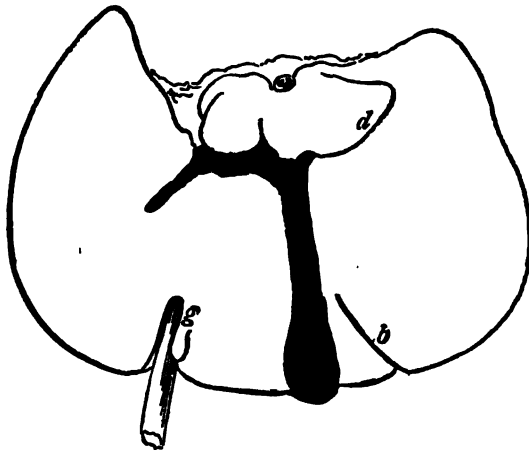


FIG. 9.—Orang.

in the position of the fissure *b* in fig. 8, thus indicating a tendency similar to that represented in the human foetal livers of a further subdivision of the right lobe (see fig. 9, *b*).

In the department of Comparative Anatomy at Oxford there is a specimen of the liver of a chimpanzee and also one of a young gorilla. The former presents no unusual features: in it, the caudate lobe is free, but otherwise it conforms to the arrangement of lobes displayed in man. The liver of the young gorilla is, however, a very interesting one: it agrees with the specimen figured by Bischoff, in that there is no subdivision of

the left lobe, an arrangement which seems to be the more common, but further displays a partial disappearance of the complete fissuring of the right lobe which is so characteristic a feature in the liver of this ape. As may be seen by a reference to fig. 10, it will be evident that whilst fissure *b* is *complete*,

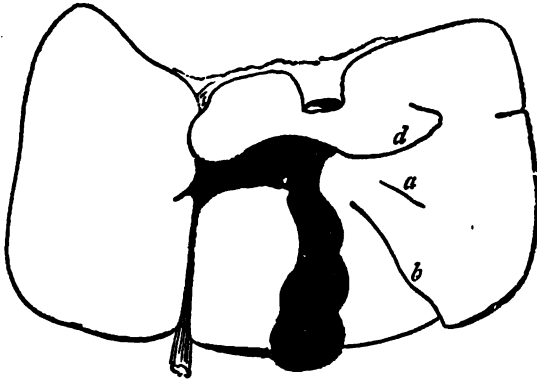


FIG. 10.—Young Gorilla.

fissure *a* is only *partial*, thus indicating that fusion has taken place, resulting in a condition in close correspondence with that represented in the orang (fig. 9), and approaching more closely the form characteristic of man and the chimpanzee, with the latter of which, however, it agrees in the separation of its caudate lobe, *d*.

According to Owen,¹ the typical form of the liver in mammals is one in which there is a central lobe fissured by the umbilical vein and the gall-bladder, the interval between which in man corresponds to the quadrate lobe. On either side of the central lobe, and separated from it by fissures, are the right and left lobes; these are variously subdivided, the right more frequently than the left. In man, owing to the disappearance of the fissures between the central and lateral lobes, the liver assumes a bilobed appearance, the lobes lying to right and left, respectively, of the umbilical fissure. As will be seen from the above description, the liver of the gorilla (see fig. 12) conforms more closely to the mammalian type, for in it the central lobe, which contains the fissure for the gall-bladder and for the umbilical

¹ *Anatomy of Vertebrates.*

vein, is flanked on either side by lobes which are separated from it by deep clefts. In this connection, however, it is interesting to note that the liver of the gorilla described by Bischoff (see *ante*) and that mentioned by me above (fig. 10) differ from the others recorded in that the fissure between the central lobe and the left lobe has disappeared, thus indicating an intermediate condition between that seen in lower and higher forms.

In view of these facts we are, I think, in a position to assign a certain significance to the fissures so frequently present on the under surface of the foetal human liver. One most noteworthy feature of the foetal liver in man is the size and development of the Spigelian lobe, and its right lateral extension, the caudate lobe. The tuberculum papillare is projecting and prominent, and bounds anteriorly and inferiorly a shallow groove in which the oesophagus is placed. In front and below, the Spigelian lobe is always deeply notched by a groove between the tuberculum papillare and the root of the caudate lobe. This groove, which often takes the form of a deep cleft, has lodged within it the hepatic artery, a relationship not sufficiently recognised in the adult, where it obtains in a less marked degree, owing to the relatively smaller projection of the tuberculum and the caudate lobe. Henle¹ mentions this relationship of the hepatic artery; but Retterer,² though he dwells at length upon the relations of the hepatic artery to the portal vein, makes no mention of it. In our text-books we are too much inclined to regard the foramen of Winslow as a space, forgetful of the fact that it does not exist as such till something is thrust through it; normally, then, the inferior edge of the foramen in which the hepatic artery is contained lies in contact with the posterior surface and inferior border of the Spigelian lobe.

Of special significance is the occurrence of the fissure *d* (fig. 8), which separates the caudate lobe from the under surface of the right lobe. This condition was met with in different degrees in nine out of the twenty-four foetal livers examined in its less developed form; it existed as an extension from the right end of the hilum, leading towards the right in front of the caudate lobe.

¹ *Handbuch der Anatomie*, 1868, p. 159.

² *Journal de l'Anatomie*, 1893, p. 238.

In its better marked condition, of which there are two examples in my collection, the fissure curved backwards round the end of the caudate lobe so as to free its extremity, which could be raised from the surrounding liver substance (see fig. 7). Here, then, we have a persistence of the condition characteristic of the chimpanzee (see fig. 11, *d*), and occasionally met with in the orang, a suggestion of the more complete degree of separation of the caudate lobe which is met with in the gorilla. The fissures *a* and *b* in the human livers are, I think, survivals of the fissured and divided condition of the right lobe which obtains most commonly in the gorilla, but of which there is ordinarily no trace in

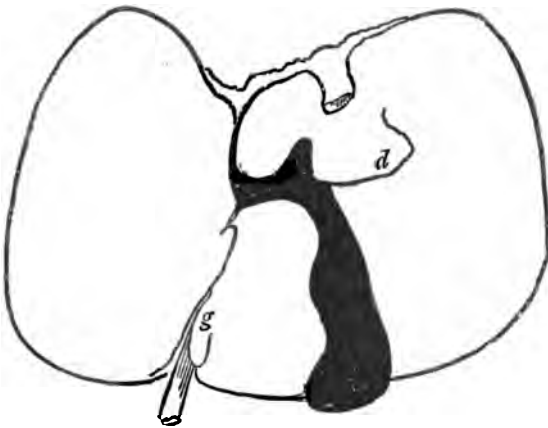


FIG. 11.—Chimpanzee.

the chimpanzee, orang, and gibbon; in this connection, however, it must be borne in mind that the number of specimens of livers of the latter anthropoid at our disposal for reference is comparatively few, and that, doubtless, were we able to examine a larger number or obtain access to foetal specimens, we would be able to obtain more evidence of the existence of such fissures. In only one specimen of a chimpanzee's liver which I examined was there a suggestion of fissure *b*, whilst the condition represented in the orang (fig. 9) is certainly suggestive of a tendency to subdivision. In this connection, too, the transitional forms of the liver of the gorilla figured by Bischoff and the young specimen herein described (fig. 10) go far to prove

that as we ascend the scale there is a tendency for obliteration of these fissures to occur, whilst at times there are instances of a reversion to a lower type.

The arrangement of the fissures *a* and *b* which occurred in combination in ten out of the twenty-four foetal livers may perhaps be best explained by reference to the arrangement of the fissure which subdivides the right lobe of the liver of a gorilla which I examined. Fig. 12, which represents diagrammatically the appearance presented by this specimen, No. 804 B 6 in the Collection of the Royal College of Surgeons of England, displays

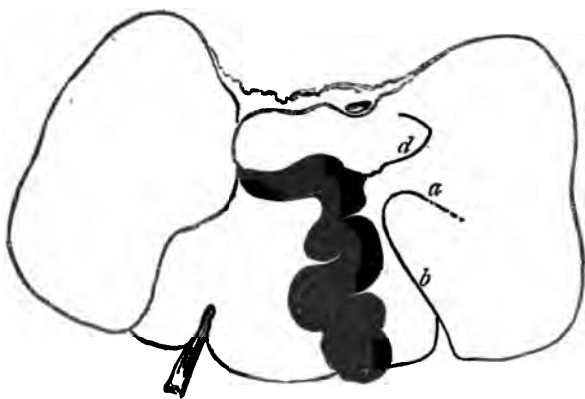


FIG. 12.—Gorilla, R.C.S.

the angular form of the fissure, the limbs of which, marked *a* and *b* respectively, seem to me to correspond in position and direction to those figured *a* and *b* in the foetal human series; the limb *a* of the fissure being distinct and separate from that which serves to sever the caudate lobe from the surrounding liver tissue. We are, I think, therefore justified in assuming that the repeated occurrence of these fissures *a* and *b*, either partial or complete, in the series of human foetal specimens, is a partial persistence of a condition characteristic of lower forms.

With regard to the fissure marked *c* in the foetal livers, we have, I think, sufficient reasons for assuming that the fissure for the gall-bladder antecedes the appearance of that vesicle as shown in figs. 1 and 3, and the occurrence of this cleft in 41 p.c. of the specimens examined supports the view that it is not merely

an accidental occurrence. A similar condition in the liver of a foetal gorilla is figured by Deniker.¹ Though in man the gall-bladder may perhaps be better described as lying in a fossa, the foregoing facts would lead us to believe that that fossa is formed by the eversion of the lips of a primitive fissure. In lower forms we know that the gall-bladder occupies a much deeper cleft, in some instances piercing the substance of the liver, and appearing at a round opening on the convex surface (opossum). Apparently, therefore, the deeper cleavage of the liver substance is a reversion to a lower type.

The disappearance and effacement of these primitive fissures *a*, *b*, and *c* appear to be due to the compression which is associated with the more compact and consolidated form of liver characteristic of man.

With regard to the significance of fissures *e* and *f*—see figs. 3, 4, 5, and 7—I am not prepared to offer any suggestions. The recurrence of *e* in four out of the twenty-four specimens seems to hint at some atavistic tendency; and I have noticed its occurrence in *Macacus cynomolgus* (804 C, Royal College of Surgeons Collection). Turning our attention next to the occurrence of accessory lobules, I have been struck by the recurrence in twelve out of the twenty-four foetal specimens of a small tongue-like lobule, shown in figs. 1, 3, 5, 6, and 7, *g*. Springing from the right lip of the umbilical fissure, near its anterior extremity, it projects forward as a pointed process, displaying a remarkable uniformity of shape and position in the cases in which it was observed. I have noticed its presence in the livers of three chimpanzees, one gorilla, and two orangs, and its occurrence in adult human livers will be subsequently referred to. The form and appearance of this lobule is not in any way influenced by the obliteration of the umbilical fissure, and appears to be an altogether independent outgrowth.

In fig. 5, *h*, another lobule of small size is shown nipped off from the margin of the right antero-lateral angle. The same condition was noticed in another specimen, and its occurrence in adult forms will also be noted.

Regarding the umbilical fissure in the foetal specimens, I find it open throughout its entire length in half (50 p.c.) the livers

¹ *Archiv. de Zool. Expériment.*, 1885.

examined. In one case it was almost completely obliterated, the vein running through a tunnel in the liver substance, whilst in the remaining eleven instances it was crossed by a pons hepatis of variable width.

Turning our attention next to the occurrence and persistence of these clefts after birth, I may say that since I commenced this enquiry I have not had the opportunity of making a large number of observations on adult or youthful forms; that could, of course, best be done where one has access to the post-mortem rooms of a large hospital. I have therefore had to content myself with the examination of store and museum preparations, though I have long been familiar with the repeated occurrence of these fissures in post-mortem specimens. Moreover, I am aware that among pathologists the presence of these clefts has given rise to the suspicion that they were the results of cicatrisation. It is well, therefore, to be able to shed some light on their true significance.

For the purposes of this enquiry I had only 13 specimens at my disposal; of these nine were adults; the other four, children ranging in age from $1\frac{1}{2}$ to 7 years. With one exception I was able to find some trace of the fissures, which I have figured and described in the foetus. The results have been recorded in the table shown on p. 552. As in the foetus, so in the adult, fissures *a* and *b* are those characterised by their frequency: *a* in the partial or complete form occurs ten times out of 13 specimens, whilst *b* occurs no less than eight times; fissure *c* was noted only twice, as also was fissure *e*, whilst no evidence was forthcoming of the presence of fissures *d* or *f*. But whilst the foregoing fissures were observed in the adult and youthful forms, it is well to add that they all displayed a marked tendency to undergo obliteration, and were not, as a rule, so well marked, either as regards depth or length, as displayed in the foetal forms. Yet their significance remains the same, their presence serving to indicate an ancestral condition in which the liver was much more subdivided. The number of specimens is too small to draw any very satisfactory conclusions from, yet large enough to indicate that the subdivision of the right lobe into two is a more persistent condition than the separation of the caudate lobe from the surrounding part of the right lobe.

This, no doubt, is correlated with the reduction in size of the caudate lobe, which in the adult presents a proportionately much smaller size than in the foetus; and hence the caudate fissure, if such cleft *d* may be called, is more likely to undergo obliteration. It is a remarkable fact that fissure *e*, the occurrence of which could not be explained in the foetus, persists in two cases in the adult. As has been already stated, the presence of such a fissure was noticed in a Macaque monkey. Interesting, too, is the persistence in three adult livers of the little lobule referred to in the foetus (fig. 5, *g*); its form, position, and proportionate size were the same. The same, it will be remembered, has been noticed as occurring in the chimpanzee, orang, and gorilla. In one adult only have I seen anything resembling the lobule referred to at *h* (fig. 5).

CONCLUSIONS.

1. Among the anthropoids the liver of the gorilla displays the greatest subdivision,—the usual arrangement being a separate caudate lobe, and a subdivided right and left lobe. In two instances (Bischoff's and my own) the left lobe is undivided. In the case recorded by me, the subdivision of the right lobe is less complete than is ordinarily the case.

2. In the chimpanzee, orang, and gibbon the caudate lobe is usually separate, though exceptions to this rule occur in the orang and gibbon,—the latter more closely resembling the appearance displayed in man.

In one orang there was partial subdivision of the right lobe, and in one chimpanzee there was a trace of such splitting up of that lobe.

3. In the human foetus the liver is remarkable for the proportionate size and prominence of the Spigelian and caudate lobes. The latter in many instances is separated from the right lobe by a deep fissure which runs along its anterior border. . In two instances this fissure was recurved at its extremity, so as partially to free the caudate lobe from the surrounding liver substance,—a condition comparable to that met with in the anthropoids.

The frequent occurrence of fissures, either complete or partial

and single or double, extending obliquely across the under surface of the right lobe, points to the persistence of the subdivided condition characteristic of the liver of the gorilla, and also met with in one instance in the orang.

The gall-bladder appears to develop along the bottom of a fissure which extends forwards to the anterior border, and which apparently is formed prior to the appearance of the vesicle.

Other fissures, marked *e* and *f* in the figures and text, are also met with. No explanation can be offered to account for their appearance. They persist, however, in the adult, and have been met with in lower forms.

The occurrence of a small lobule (*g* in the figures) is a common feature: it is met with in the anthropoids, and frequently persists in the adult.

Another lobule (*h* in the figures) has also been met with. This also has been noticed in adult forms.

4. The appearance of anomalous fissures and clefts on the under surface of the right lobe of the adult human liver is thus accounted for by a reference to the foetal condition, and a comparison with the arrangement of the lobes in the anthropoids.

ON THE TOPOGRAPHICAL ANATOMY OF ABDOMINAL
VISCERA IN MAN, ESPECIALLY THE GASTRO-IN-
TESTINAL CANAL.¹ PART I. By CHRISTOPHER ADDISON,
M.D., B.S. (Lond.), F.R.C.S., *Professor of Anatomy, University
College, Sheffield.* (PLATES XLIII.-XLIV.)

At the beginning of this paper I wish to acknowledge my great indebtedness to those who have so materially and so generously helped me,—particularly to Dr Claye Shaw and the Medical Officers of the London County Asylum, Banstead; and to Mr Waters, the Master, and the Medical Officers at the Fir Vale Union, Sheffield. At Banstead, the mortuary was placed at my disposal, and almost unlimited time and opportunity were afforded me. I cannot thank Dr Claye Shaw too much. To Drs Jones and Bond I also owe special thanks. The same facilities were afforded me at Fir Vale; and, in addition to Mr Waters, I must thank Drs Sorley and Waddy for their kind help. My thanks are also due to Drs Garrod and Calvert at St Bartholomew's for the work I was able to do there, and to Mr C. W. Smith, my Prosector, for drawing Figs. 3A and 3B, and for help with the Tables.

PURPOSE OF INQUIRY.

With the advance of medical and surgical science, especially with regard to the operations of surgery on the abdomen, the topography of the abdominal viscera becomes of increasing importance.

The method of determining the position of the underlying parts should be as simple as possible, it should be convenient of application, and, withal, having regard to the varying conditions of the abdominal organs, as accurate as can be. One seldom meets with an abdomen which can be called normal in all respects.

Very many accurate and extended measurements of various

¹ Read before the Royal Society, December 8, 1898. Communicated by Professor Alexander Macalister, F.R.S.

organs have been published at different times, but these, though exact in themselves, do not thereby enable us to form an adequate anticipation of the shape or position of particular organs, if they themselves, or adjoining organs, abdominal or thoracic, are enlarged or diminished in size, or altered in position, through any cause whatever. Notwithstanding that the enlargements and alterations in any one organ may in some cases be quite obvious on superficial examination, this does not carry with it the information as to what deviation from the usual position we may expect in the neighbouring parts. From the point of view of practice, abdominal organs must be considered collectively as well as singly. Moreover, the present methods of abdominal topography, in regard to surface-points, leave something to be desired. This is sufficiently evidenced by the diversity of the methods employed amongst anatomical authorities.

In undertaking this research, therefore, it seemed to promise the greatest utility if certain regular surface-points were taken which would be quite independent in themselves of such movable parts as the costal cartilages or the umbilicus, and which, whilst retaining, as far as may be useful, those parts as adjuncts, would be unvarying, and easily determined in any particular body. Having obtained these surface-points, the various abdominal viscera were measured, and their position in regard to the surface-points determined. Further, taking account of the varying mutual relations of the viscera, as far as the series allowed, indications were sought for of the alterations in position or shape which are to be expected under different conditions.

It was recognised that it was important that this should be done, whilst retaining the use of those terms of abdominal topography which have become established by usage, and with the least possible disturbance of their present significance.

Briefly, therefore, the purpose of this inquiry has been to carefully map out the abdominal viscera in relation to well-defined uniformly-proportioned surface lines, and to ascertain, as far as possible, the modes in which the abdominal viscera alter their position, or are displaced, when they themselves, or the viscera in their neighbourhood, are enlarged or diminished in size, or pressed upon by neighbouring parts.

PROF. ADDISON ON ABDOMINAL VISCERA IN MAN.

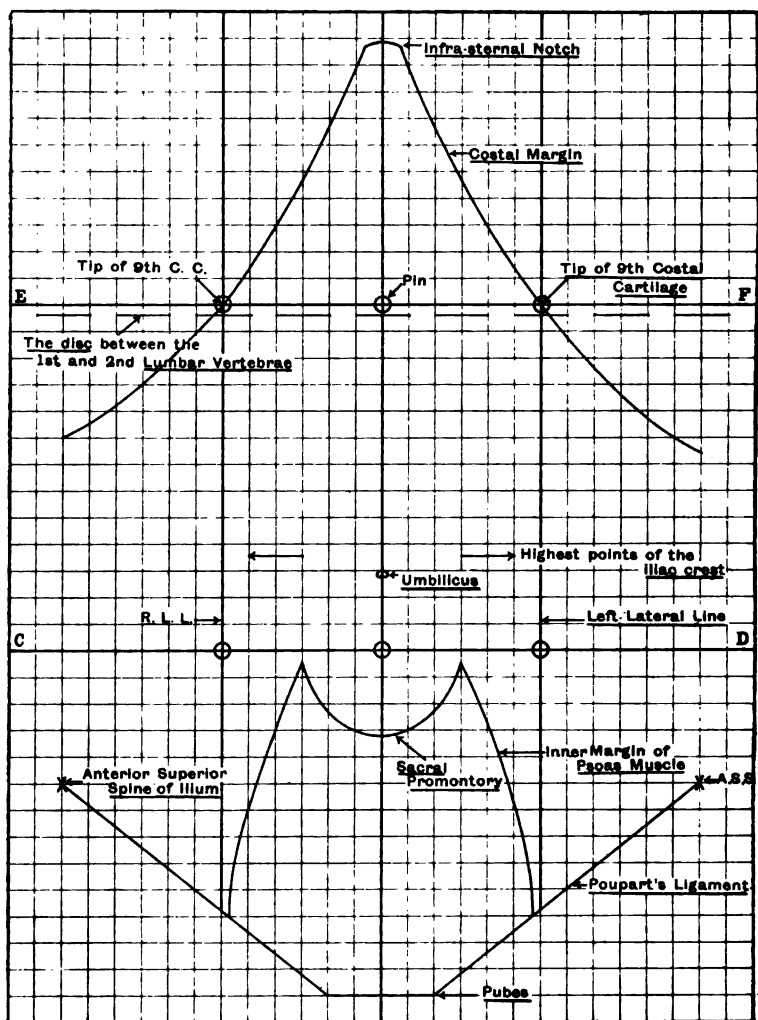


FIG. 1.—Diagram showing the average position of the landmarks whereby the abdominal regions are limited.

DELIMITATION OF THE REGIONS OF THE ABDOMEN.

In all cases the subject is laid flat on the back on a table, the legs extended and in a straight line with the trunk, the arms drawn evenly down by the side, and the head resting extended on the table.

The abdomen is divided *vertically* by three lines—a median line and two lateral lines.

The lateral lines are drawn vertically upwards, one on each side, through a point half way between the anterior superior iliac spine and the middle line, in a line drawn transversely across between the two anterior superior iliac spines.

The body is divided *transversely* by lines drawn across at points a quarter, a half, and three-quarters of the way along a line drawn from the upper border of the pubes to the supra-sternal notch. The uppermost transverse line we are not much concerned with. It passes across the thorax as a rule, 3·2 centimetres above the lower border of the body of the sternum. In Figure 1, and in the printed tables, it is spoken of as the line X.Y.

The *upper transverse abdominal line*, half way from the pubes to the supra-sternal notch, is spoken of as *the line E.F.* The *lower transverse abdominal line*, a quarter of the way from the pubes to the supra-sternal notch, is spoken of as *the line C.D.*

With regard to the vertical lines, the median line is most useful, both for the equal division of the abdomen and for the purposes of measurement, both vertically and transversely. The lateral lines correspond with those generally in use at present. The method used for determining them is more accurate than by taking the mid-point of Poupart's ligament, for this is a point not easy to determine exactly. Lines drawn obliquely upwards, such as those used by Macalister (1), from the spine of the pubes to the 8th costal cartilage, seem objectionable, because of the variations of the 8th costal cartilage, and because the lines divide the abdomen unequally.

With regard to the lines generally used to divide the abdomen transversely, they are open to the great objection that the distance between them varies very much. In the case of

the upper one, there is much difference between various writers as to the points between which it is drawn. If the line is drawn across between the tips of any particular costal cartilages—points which in large numbers of cases are very difficult, if not impossible, to determine—or between the lower border of the 10th costal cartilages, as Cunningham (2) advises, in many cases it does not pass horizontally. Moreover, the distance between the two transverse lines is often much less than the distances above or below them, to the sternum and pubes respectively; and the wide variations in the level of the upper transverse line are too considerable to make it a satisfactory line to use in any research on the topography of the viscera. In Cunningham's paper, he gives the average distance between the transverse lines as 2·7 inches, the average depth of the costal zone, above the upper line, as 6 inches; of the hypogastric zone, below the lower line, as 5 inches. Considering the very important structures in the costal zone, 6 inches is too great a length to allow without a surface line. A line is desirable in this region, at a somewhat higher level, if one can be found, which has a fairly constant significance.

Concerning the lower transverse line, without discussing the various positions in which it has been placed, it may be said the line C.D. practically corresponds with Cunningham's intertubercular line, drawn across between the two tubercles situated on the outer aspects of the iliac crests.

My purpose, however, in selecting the transverse lines I have described, was simply the obtaining of easily-found, equidistant points for the purpose of measurement; and I was not prepared for the regularity of position in regard to the vertebræ and other structures which, especially, the upper transverse line E.E. has been found to possess. It corresponds almost accurately to the disc between the 1st and 2nd lumbar vertebræ, and cuts the junction of the 8th and 9th costal cartilages at the tip of the 9th.

The lower line C.D. passes across on an average 5 cm. above the anterior superior iliac spine, and 3·5 cm. below the highest point of the iliac crest.

The consequence of this division of the abdomen, as will be seen on reference to fig. 1, is that there are right and left

epigastric, umbilical, and hypogastric regions, with right and left iliac and lumbar regions, and with the hypochondriac parts of the abdominal cavity, not, as a rule, extending from under cover of the costal cartilages. This limitation of the hypochondriac region, I think, will be seen not to possess any disadvantage, whereas the increase of the lumbar region is to be desired.

METHOD OF EXAMINATION.¹

The study of the relative anatomy of the abdominal viscera has been materially advanced of late years by methods of hardening the body by fluid injections, and, subsequently, dividing it into a series of sections, from which accurate models of the viscera in the hardened state have been built up. In various manners these hardening methods have been employed by His (3), Cunningham (4), Symington (5), Birmingham (6), Weinburg (7), Sernoff (8), and others.

For the obtaining of a series of accurate observations on the mutual as well as on the individual relations of the viscera, the hardening method gives perhaps the most reliable results; yet it is so very difficult of application to a large number of cases that it should be, if possible, supplemented by some other method, if such can be found to be trustworthy. The first two bodies of this series were hardened before examination by the injection on the 3rd, 4th, 5th, and 7th days after death of two quarts of 5 per cent. solution of formic aldehyde. It was cold weather during the whole time that the bodies lay on the table, and there was frost each night. The viscera and the muscles were quite firm, and retained exactly the impressions produced on them by surrounding parts. The abdomens of six other bodies, similarly hardened, have been used,—three for dissection, and three for the examination of special points and for the making of preparations.

In all cases the time after death when the examination was made was noted; and the condition of the nutrition of the body in such general terms as 'emaciated,' 'fair,' 'good' or 'fat,' and any special pathological or other condition, or obvious displacement

¹ In all cases where convenient, figures are used instead of written numbers.

or distension of organs was described. Furthermore, the state of the various viscera, whether soft or firm, was specifically stated.

The distance from the pubes to the supra-sternal notch is measured by drawing the tape tightly between these points. If the abdomen is convex, the half-way point is marked directly; if concave, the spot directly beneath the mid-point of the tape is taken; and at this point, after a small skin incision, a long steel pin is driven through the abdomen. This marks the level of the upper transverse abdominal line (E.F.).

In a similar way, beneath the quarter-way point the level of the lower transverse abdominal line (C.D.) is determined, and a second pin is driven through the abdomen at this point.

The position of the lateral lines, half way from the anterior superior iliac spines to the middle lines, is then determined, and four more pins are then driven through the abdomen, one in each lateral line in the planes of C.D. and E.F. If the abdomen between the anterior superior iliac spines is convex forwards beyond them, or is unequally distended, as in the case of a distended cæcum, the measurement between them is taken on a projection forwards, and is confirmed on opening the abdomen.

The distances vertically upwards from Poupart's ligament along the lateral lines, from the anterior superior iliac spines, and from the highest point of the iliac crests to the costal arch or ribs, are then measured, and the parts met with, as felt through the skin, are noted. On opening the abdomen, these points are confirmed or corrected, and a drawing of the costal arch is made. For the drawing, the distances of the tips of the different cartilages from the infra-sternal notch are measured along the costal margin, the transverse width of the arch in the plane of E.F., between the tips of the 10th costal cartilages, or other suitable points according to the arch, are also taken, and the differences in level, if any, of the points cut by the lateral lines as they impinge on the arch and the plane of E.F., and the difference in width, if any, at these levels.

The distances above or below the transverse line C.D. of the anterior superior iliac spines, the highest points of the iliac crests and the umbilicus, and the infra-sternal notch above E.F., and below the upper transverse line X.Y., are measured. The

greatest transverse diameter of the body in the planes C.D. and E.F., and the cartilages, intercostal spaces, and ribs, cut by prolonging the lines E.F. and X.Y. transversely, are noted. At the conclusion of the examination the relations are obtained of the upper median pin to the disc between the 1st and 2nd lumbar vertebræ, and of the lower pin to the aortic bifurcation, to the disc between the 4th and 5th lumbar vertebræ, and to the pelvic brim in the middle line,—the pelvic brim in the middle line being variously the upper border of the 1st sacral vertebra, the disc between the 5th lumbar and the 1st sacral, or the lower border of the 5th lumbar vertebra, according to the tilt of the spine. Finally, the brim of the pelvis, as measured between the inner margins of the psoas muscles, is fully drawn in its relation to C.D. and Poupart's ligament.

In this way a complete map of the superficial and deep points in their relations to the lines of division is obtained, so that the measurement of the viscera projected on to the surface in relation to the lines I have adopted can, if these be not found convenient, be transferred to any other system of surface divisions whatever.

The steel pins used to transfix the abdomen are 14 inches in length, with a long sharpened point and an expanded head, and as thin as is consistent with absolute rigidity. They were driven in with the utmost care at the exact distances from one another, and at right angles to the table. They were made so long in order that, as they project for some inches from the front abdominal wall, the slightest obliquity might be obvious. For it is clear that even a small degree of obliquity in the case of a thick abdomen would lead to the point of the pin entering the back wall a centimetre or more higher or lower, as the case might be. I can only say that the pins were always driven in with the utmost care; and I think the degrees of error are so small that, in the whole series, they will fairly correct one another.

The median and lower lateral pins fasten themselves in the vertebræ and iliac bones respectively.

The upper lateral pins, which passed free of, at the margin of, or through the costal cartilages, as the case may be, were driven through into the table in the cases in which it was wood. For

the rest, in those cases in which they did not fasten themselves, by transfixing the costal cartilages, after the stomach and liver had been removed, it was sometimes necessary to fix the tops of the pins; but as the pins were in no cases removed, and the measurements of the viscera on the posterior abdominal wall were taken immediately from the pin at the point of its transfixion of them, the accuracy of the measurements was not interfered with.

Printed tables were used for recording the surface measurements, and large sheets, ruled after the manner of the surface lines, were employed for making the rough diagrams of the viscera, and for recording in centimetres at various points along the diagrams the distances of the parts from the pins. The measurements in the abdomen were taken with a stiff steel measure, graduated in centimetres.

The abdomen was opened by a median incision, and transverse incisions in the planes of C.D. and E.F. to clear the pins. The lower transverse incisions were sometimes prolonged even further outward than the pins. A drawing was made of the costal arch when it was cleared. The great omentum was measured and its free border represented by a line, and the distances above, below, to the right or left of the different pins marked in figures. The omentum was then cut away, and as far as possible the cæcum, the transverse colon, the lower border of the stomach, and the lower border of the liver were measured and drawn, and the general course (but not representing accurate measurements or figures) of the superficial convolutions of the small intestines was indicated by a line. The lower border of the liver was then, if necessary, cut away or lifted up to permit of measurement of the pylorus, the lesser curvature, and the cardiac orifice of the stomach. The upper border of the liver, to the left, and in the middle and lateral lines, was taken by passing the rod along its anterior surface to its upper border. Although in general easy, the measurements of the upper border of the liver and of the summit of the stomach were sometimes attended with considerable difficulty, as the organs were tightly jammed up beneath the ribs. In such cases, either the anterior abdominal wall was transfixed higher up until the proper level had been obtained, or some of the ribs and cartilages in front were cut away and lifted up as much as was necessary. The right border

of the liver, the gall-bladder, the hepatic flexure of the colon, the highest point of the splenic flexure of the colon, and the greater curvature of the stomach at the left were then measured in the order they presented, and the splenic flexure of the colon or the descending colon, as the case might be, down to the plane of E.F.; overlying parts being lifted up or cut away as was necessary. At this stage the small intestines were cut away piecemeal and the length of the mesentery measured, and diagrams and measurements made of the ileo-cæcal region, of the ascending, descending, and sigmoid colons, of the commencement of the rectum, and of the brim of the pelvis. The stomach and liver were then cut away. The previous measurements, if any, of the duodenum were completed and confirmed, the pancreas, kidneys, spleen, supra-renal bodies, the vena cava, and the parts of the back abdominal were measured and filled in.

The foregoing order of examination was necessarily subject to variations in different abdomens. No part was disturbed before measurement, and any obstructing part was cut away piecemeal to expose it. Often, of course, it was very laborious and difficult, but the greatest care was taken; and I am convinced that, except where otherwise so stated in the tables, the measurements are substantially accurate.

The line of the attachment of the mesentery and of the peritoneum along the ascending and descending colons, and of the lower layer of the transverse meso-colon, was marked and measured, and any peritoneal bands or pouches drawn. The time occupied in making the post-mortem was, as a rule, four hours. Two or three of the large ruled sheets were used for marking in the viscera and recording the distances at various points from the pins; also sundry accessory sheets were used for diagrams of special parts, such as the ileo-cæcal region.

Subsequently, the diagrams were worked out on the life-size scale on sheets ruled in centimetre squares (see figs. 3A and 3B). At the risk of some complexity, for the sake of having in one place a representation of the mutual relations of the viscera, I outlined all the organs of each case on one sheet in various colours. The individual organs from the whole series are presented collectively on the scale of one-ninth in the figures embodied in this paper.

In all cases, except where specially drawn or stated, on the ground both of convenience and utility, the forward projection of the viscera is the only one represented. It is difficult, if not impossible, in a considerable proportion of persons, to satisfactorily map out the various bony points on the back.

This paper is written on the basis of the complete measurement in the manner described of 40 subjects—full details of each case being presented in the Tables in the Appendix.

The cases are consecutive, and not selected at all, being taken only according to time and opportunity.

Case 8, however, is an exception. It is really the twenty-first. The case originally numbered 8 had been done hurriedly, and after the first twenty were completed it was decided to omit it altogether from the series, as it was found that many measurements and notes had been omitted. The next coming case, No. 21, was therefore substituted for it. In addition to these 40 cases, various other illustrative preparations were made.

The main subject of inquiry has been the topography of the gastro-intestinal canal, but it was quite impossible adequately to consider it without including the other abdominal viscera, except the pelvic.

Although 40 cases are presented in this paper and averages are drawn from them, it is fully recognised that, in the case of many of the averages, much more extended observations are necessary.



PROF. ADDISON ON ABDOMINAL VISCERA IN MAN.

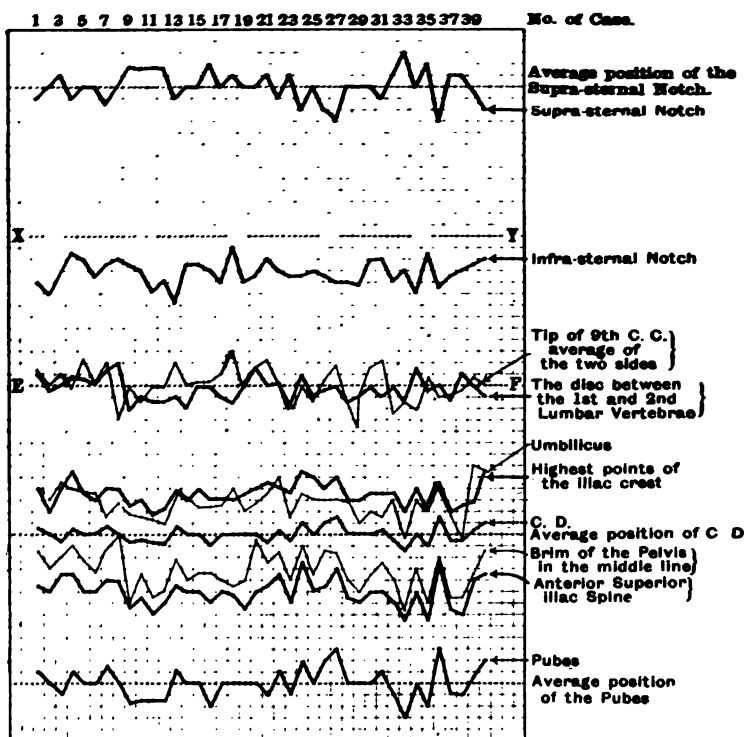


FIG. 2.—The curves show the variations in position of different superficial and deep points in regard to the upper (X, Y), middle (E, F), and lower (C, D) transverse lines. Scale—Each square represents 1 square centimetre.

TABLE I.

Table of Averages of Surface Measurements.

	Age	45.6 years.
	Height	5 ft. 3½ inches, about 160 cm.
Distance from the pubes to the suprasternal notch,		52.0 cm.
„ between the transverse lines		13.0 „
„ of the infra-sternal notch above E.F.,		9.8 „
„ of the infra-sternal notch below X.Y.,		3.2 „
„ of the sacral promontory below C.D.,		3.2 „
„ of the anterior superior iliac spine below C.D.,		5.0 „
„ of the umbilicus above C.D.,		2.7 „
„ of the iliac crest (highest point) above C.D.,		3.5 „
„ of the aortic bifurcation above C.D.,		2.0 „
„ alone the lateral line to the costal arch—right,		24.8 „
„ „ „ „ „ left,		24.8 „
„ from the ant. sup. iliac spine to the „ right,		13.0 „
„ „ „ „ „ left,		12.5 „
„ from the iliac crest (highest point) „ right,		4.8 „
„ „ „ „ „ left,		4.7 „
„ between the ant. sup. iliac spines,		23.8 „
¹ „ of the lateral lines from the middle line,		5.95 „
Width of the body in the plane of C.D.,		29.0 „
„ „ „ „ E.F.,		26.5 „
„ across the costal arch,		12.1 „
Part of the costal arch cut by E.F.—right	Junction of 8 and 9 costal cartilages at the tip of 9th.	
„ „ „ „ —left		

The level of the point on the costal arch cut by the lateral line as to E.F.; right—corresponds with E.F.; left—12.5 cm. below E.F.

The relation of E.F. to the disc between the 1st and 2nd lumbar vertebræ, 33 cm. above.

¹ Note.—These measurements, representing a quarter of the preceding, are shown on figs. 3A and 3B as 6 cm., which is sufficiently accurate for practical purposes.

Compare fig. 1 facing page 567.

SURFACE POINTS AND MEASUREMENTS.

Height.—There were 12 females and 28 males examined. Only two subjects were under twenty years of age—these being a female, æt. 16, 4 feet 10 inches in height; and a male, æt. 13, 4 feet 6½ inches in height. The average age was 45½ years. The average height 5 feet 3½ inches, or about 160 centimetres.

The average distance from the pubes to the supra-sternal notch was nearly a third of the height, namely, 52 cm. This distance varied very little: 14 cases were 52 cm. exactly, 5 were

from 50 to 52 cm., 5 from 48 to 50 cm., 7 were 54 cm., and 6 from 54 to 56 cm. One case, a male of 5 feet 5 inches in height, was 58 cm., and two cases were only 46 cm.; being respectively, a male 4 feet 6½ inches in height, and a female 4 feet 7 inches in height.

The average length of the abdominal part of the trunk was 35.8 cm., leaving the manubrium and body of the sternum a total average length of 16.2 cm., or 9.8 per cent. of the total height of the individual. Wright (9) gives the average for males as 9.65 per cent., and for females 9.22 per cent.

The average distance between the transverse lines was 13 cm., or a little over 5 inches. The average distance of the infra-sternal notch¹ above E.F. was 9.8 cm., nearly 4 inches, thus leaving a not too large interval between the body of the sternum and the upper transverse abdominal line. The maximum in this distance was 11.5 cm., and occurred only in 2 cases, and there were only 2 cases in which the distance was less than 8 cm.:—these cases being 7.25 cm. and 7.75 cm. respectively. In such a diversity of subjects, with so different characters of the chest and abdomen, this variation is small.

The line E.F.—Since the mid-point of the distance from the pubes to the supra-sternal notch is taken quite regardless of the condition of the body, whether fat or thin, with the abdomen or chest distended or not, the regularity of the position found to be occupied by the line E.F. renders it a most useful line for surface marking. The variations are fully shown on the curves in fig. 2. In regard to the vertebral column:—The average position it occupied was in the body of the 1st lumbar vertebra 33 cm. above the disc between the 1st and 2nd lumbar vertebrae. The variations from this disc were very small: in 12 cases the pin pierced the disc; in 15 cases it was 1 cm. or less from the disc; in 9 others the pin was more than 1 cm. but less than 2 cm. from the disc; thus giving 36 cases, or 90 per cent., in which the pin was less than 2 cm. from the

¹ By the infra-sternal notch is meant the notch at the lower border of the sternum between the two 7th costal cartilages, as it can be felt and located on the surface. By the anterior superior iliac spine is meant that spot where the crest of the ilium, as felt through the skin, ceases, and where Poupart's ligament begins. The xiphoid cartilage is in all cases neglected.

disc. Of the remaining cases, the greatest variation was 2.5 cm. above. In three cases it was 2 cm.; in 2 cases above, and in 1 case below the disc.

As regards the costal arch, the line E.F. in the average position passed across exactly at the tip of the 9th costal cartilage on the right side, and a very little above it on the left (see Table I. in the Appendix). Although this was the average level of the tip of the 9th costal cartilage, yet it will be seen on reference to Table I. and to fig. 2, that this point had a wider excursion in relation to E.F. than the first lumbar intervertebral disc¹ had.

In 10 cases the level of the tip of the 9th cartilage was 2 cm. or more removed from E.F.; the greatest distance away being 3 cm. in 2 cases, one above and one below E.F. In 10 cases this point was 2 cm. or more removed from the disc, in 5 of them being from 3 cm. up to 5 cm. away. Although in the remainder of the cases the tip of the 9th costal cartilage closely followed the level of the disc, yet the extent of its variations would make it of somewhat less value than E.F. And, besides, it must be remembered that the 9th costal cartilage often tapers gradually to its extremity, and that even in quite thin persons it is not always possible to locate it.

The line C.D.—Concerning the lower transverse line C.D., its average distance was a little over 5 inches from the upper border of the pubes (13 cm.). In this region of the abdomen, as the bony points are more stable, the necessity for a transverse line, as apart from them, is not pressing. However, the line C.D. occupies a very constant position in relation to the anterior superior iliac spines. Its average distance was exactly 5 cm. vertically above them. As regards the variations:—In 2 cases the iliac spines were nearer than 4 cm. to C.D., namely, 3 cm. and 3.5 cm. In 3 cases the distance was increased beyond 6 cm., being 6.5 cm. In 26 cases, or 65.7 per cent., the line was within .5 cm. of its average level as regards the iliac spines.

The relation of C.D. to the highest part of the iliac crest was also subject to little variation. It was, on an average, on a plane 3.5 cm. lower than the highest part of the crest. Taking a centimetre each way from the average: there were 4 cases

¹ In future, for convenience, this will be termed the disc.

in which the distance was 4.5 cm. or more, up to 5 cm. below, and five in which it was 2.5 cm. or less, down to 2 cm., the maximum variation thus being 3 cm. In the remaining 31 cases (77.5 per cent.) the variation was less than a centimetre each way from the average. By combining these two statements of the relations of C.D., it will be seen that the average difference in level between the highest part of the iliac crest and the anterior superior iliac spine, as the subjects lay on the table, was 8.5 cm., or nearly $3\frac{1}{2}$ inches.

For the purposes of utility, the relation of the line C.D. in regard to the vertebral column, in the figures and in most of the tables, is referred to the brim of the pelvis in the middle line behind. Its relations, however, to the disc between the 4th and 5th lumbar vertebrae will be fully set forth in the individual case tables.

The part of the vertebral column which, looked at from the front, would be selected as the spot where the spine definitely bends backwards into the pelvis, is, variously, the lower border of the 5th lumbar vertebra, the disc between this bone and the sacrum, or the projecting upper border of the first sacral vertebra.

Wheresoever this point might be, the figures here considered refer to that point, as observed at the end of the examination, from the front. Therefore, as the tilt of the spine varied, C.D. would be expected to vary in level from this point more than from the disc between the 4th and 5th lumbar vertebrae. For the present, however, the average distance of C.D. above this point, which provisionally may be called the sacral promontory, was 3.2 cm. In 23 cases, or 57.5 per cent., the variation was not more than 1 cm. higher or lower than the average. In 9 cases the distance was 2 cm. or less, in 1 case the levels corresponded. Of the remaining 8 cases; in 6 the promontory was from 4.25 to 5 cm. below C.D., and in 2 cases more than 5 cm. up to 5.5 cm. below.

Umbilicus.—As regards the position of the umbilicus, the tables, as well as a large number of the figures, show that, however convenient the umbilicus may appear to be as a surface point, it is not sufficiently stationary in its position for purposes of precise measurement. Summarising here, however, only its

variations as regards C.D. and the iliac crest: Its average position was 2·7 cm. above C.D.; in 12 of the cases it was 3·5, up to 5·5 cm. higher; and in 7 cases it was 1·5 cm. or a less distance from C.D., in one instance being on the same level. The maximum of its variations in level, therefore, was 5·5 cm., as regards C.D.

There were 10 cases in which the umbilicus was 2 cm. or more, up to 3 cm., removed from the level of the highest part of the iliac crests, the maximum of the variation from above downwards being 6 cm. Of the remaining 30 cases, however, there were only 6 in which the difference in level between the umbilicus and the highest part of the iliac crest was as much as 1·5 cm.

Costal Arch.—The width across the costal arch in the plane of E.F. varied too much for the figures to be of any value. The average was 12·5 cm., the extremes being 6 and 18 cm. There were 8 cases with a width of 15 cm. or more, and 7 cases with a width of 9·5 cm. or less. In fact, the tables and figures show quite well that to describe any deep parts as being so much internal to, or so much beneath the costal margin is of very little utility. This, however, applies with less force to the very highest or lowest parts of the costal arch.

The total transverse diameter of the body in the plane E.F. was 26·5 cm.

The average distance across the body in the plane C.D. was 29 cm., and between the two anterior superior iliac spines was 23·8 cm. The difference between these two measurements indicates that in rising in level 5 cm., up to C.D. from the iliac spines, the crests of the ilia have widened out 1 inch on each side. There were 8 cases in which the distance between the two anterior superior iliac spines was 22 cm. or under; of which 2 were females. The smallest measurement was 19 cm.—in a man 5 ft. 4½ in. in height, 52 cm. from the pubes to the supra-sternal notch. There were 7 cases, all males, in which the distance was 26 cm. or more; the maximum distance, 28 cm., existing in 3 cases, the individuals being respectively 5 ft. 2½ in., 5 ft. 10½ in., and 5 ft. 5 in. in height, and 55, 55, and 58 cm. from the pubes to the supra-sternal notch.

The distance of the lateral line from the middle line follows

from the preceding, and needs no comment, save to point out its average was nearly 6 cm.

The distance vertically upwards from the anterior superior iliac spines to the nearest point of the costal arch varied considerably, on the right side from 9 to 18 cm., and on the left from 8.5 to 17 cm. The average on the right side was 13 cm., on the left 12.5 cm. There were 17 cases in which the distance on the right side exceeded that on the left, and 5 cases in which it was less; there being 18 cases in which the measurements were equal on the two sides. There were 23 cases on each side in which the variation was not more than 1 cm. from the average, upwards or downwards. The 10th costal cartilage was almost invariably the part struck. There were 16 cases, or 40 per cent., in which the 10th costal cartilage did not articulate with the 9th, and in most of these cases the 12th rib was noticed to be small and difficult to feel.

Iliac Crests.—The average distance from the highest part of the iliac crest vertically upwards to the nearest rib was 4.8 cm., and 4.7 cm. on the right and left sides respectively. The part met with was usually some part of the 11th rib. In 33 cases the distances on the two sides were practically equal. In 5 cases that on the right exceeded that on the left, and in 2 cases (one in which is marked doubtful) it was less. The minimum distance on the right side was 3 cm., and the maximum 8 cm.; on the left the minimum was 3 cm., and the maximum 7 cm.

Lateral Lines.—The measurement along the lateral line from Poupart's ligament to the costal arch being taken along the surface of the abdomen, does not always represent the perpendicular between these points. It is of no particular consequence in this place. The average on each side was 24.75 cm. The point on the costal arch cut by this line is, however, of much interest. In 9 cases on the right side and in 10 cases on the left it was identical with that struck by E.F., passing transversely. In 14 cases on each side the lateral line met the costal arch below the level of E.F.; there being in these cases, as well as in those in which the lines met at the costal margin, no hypochondriac region beyond the costal arch. The sum of the distances below E.F. in these 14 cases was on each side 28.5 cm. This, however, does not mean

that, in the individual cases, the distances were the same on each side; in fact, they were not often so; it merely happens that the sums of the differences below the level of E.F. are equal on the two sides. (See Table I., Appendix.)—The greatest distance below E.F. on the right side was 3·5 c.m., and on the left 4·5 c.m.

In 17 cases on the right side and in 16 cases on the left the lateral line struck the costal arch above the level of E.F., the sum of the distances above on the right side being 28·75 cm., and on the left 22·25 cm. The maximum distance above E.F. on the right was 4·5 cm., and on the left 3·5 cm. In all these cases there would be a hypochondriac region, free of the ribs, of varying extent. (See the Figures of the different viscera on the reduced scale.)

The aggregate distances above and below the level of E.F. on the right side, 28·75 and 28·5 cm., practically balance, leaving the level of the point on the costal arch on the right side, struck by the lateral line, identical, in the average, with that cut by E.F., passing transversely.

This point is the tip of the 9th costal cartilage.

On the left side, the aggregate above the level of E.F., 22·25 cm., is less than that, 28·5 cm., below, giving the point struck by the left lateral line as on the 9th costal cartilage 125 cm. below the level of E.F., which difference for practical purposes is of no account.

Hence, E.F. drawn transversely and the lateral lines drawn vertically, in the average, cut the costal arch on each side in identical points,—these points being on either side the tip of the 9th costal cartilage.

THE STOMACH.

TABLE II.

Section I.—Showing the average position of the various parts of the stomach.

M.L. signifies the middle line.

Distance of the centre of the *cardiac orifice* below the infra-sternal notch, 2.1 cm.

"	"	"	above E.F.,	7.7 "
"	"	"	to the left of M.L.,	1.0 "

The lesser curvature.

¹	The extreme left, or the left point of the lesser curvature	from M.L.,	3.8 "
		above E.F.,	4.5 "
	The lesser curvature in the middle line above E.F.,		1.9 "
	The upper border of the pylorus above E.F.,		7.6 "
	"	from M.L.,	2.0 "

The greater curvature.

	The summit of the stomach above E.F.,	9.6 "
	" below the infr-st. notch,	13 "
	" from M.L.,	5.1 "
¹	" extreme left point from M.L.,	10.7 "
	" above E.F.,	3.5 "
²	" in the left lateral line below E.F.,	1.2 "
²	" as it passes beneath the costal arch below E.F.,	.5 "
	" in the M.L. below E.F.,	2.5 "
¹	The right extremity of the stomach from M.L.,	2.8 "
	" below E.F.,	1.75 "

1. *The average position of the Stomach as regards the surface.*

Definitions.—In the table of averages, the central point of the cardiac orifice is taken for convenience, but the upper and lower borders, the position and obliquity, are fully recorded, and are shown in fig. 4 and in the Appendix. The cardiac orifice in all cases after the first was taken as that part where the œsophagus becomes free of the diaphragm and passes to the stomach. This, in all cases, is not the actual orifice, as the œsophagus

¹ These points are defined more precisely in the text.

² Although the average position of the lateral line corresponds to E.F. at the costal arch, these two averages do not necessarily correspond. See fig. 4 and in the next number of the *Journal*, Table II. (Appendix).



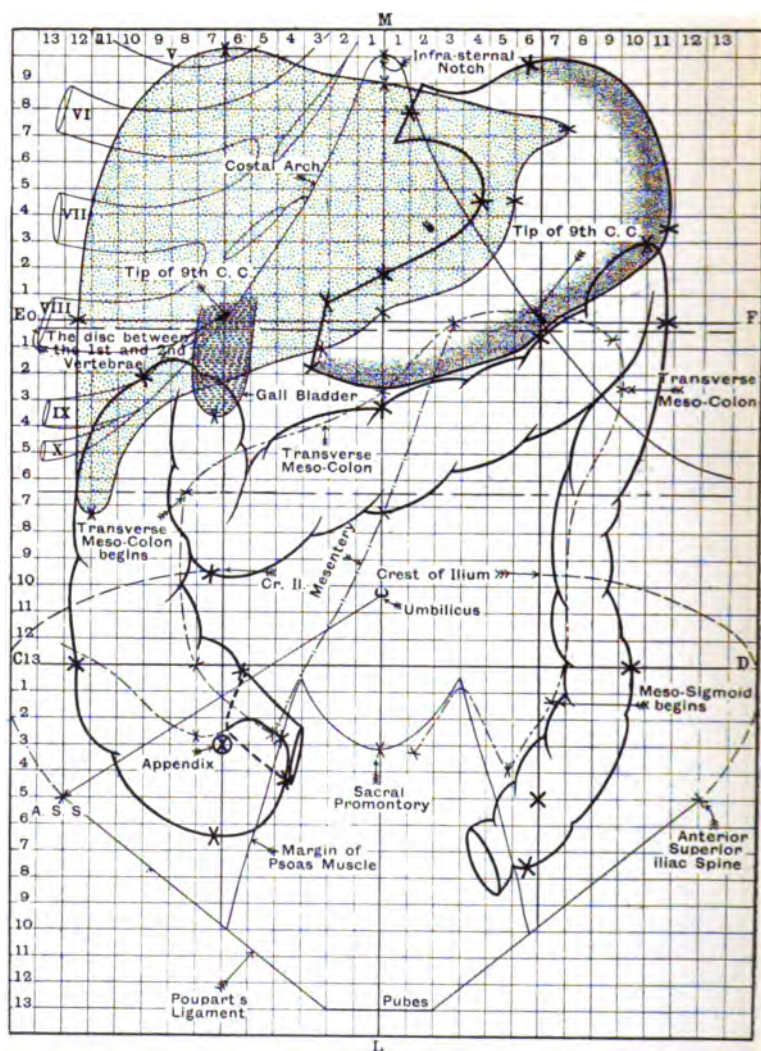


FIG. 3A.—Outline figures showing the average position of the Abdominal Viscera on a centimetre scale; reduced to '36 natural size. The lines of the peritoneal attachments are also shown. The crosses (+) indicate the position of the various "points" referred to in the text. The lettering is the same as in fig. 1. (From a drawing by C. W. SMITH.)

DOMINAL VISCERA IN MAN.

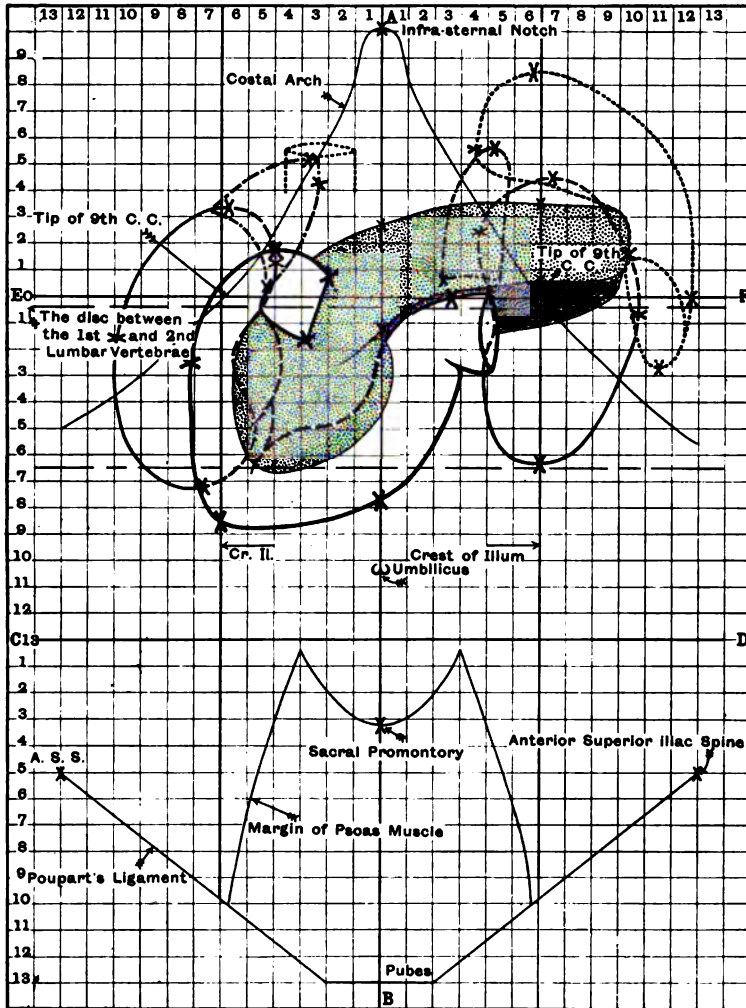


FIG. 3B.—Outlines of the deeper Abdominal Viscera constructed on the same plan as those shown in fig. 3A. (From a drawing by C. W. SMITH.)

Footnote to Figure 3A.—The arrow showing the tip of the 9th right costal cartilage should have been drawn pointing to the intersection of E. F. and the right lateral line.

The lower border of the stomach and the upper border of the transverse colon in the left lateral line should have been each represented .5 cm. lower down.

frequently passes downwards and to the left for a short distance in the abdomen before opening into the stomach. The extreme of the lesser curvature to the left is always recorded, and the point at its extreme distance from the middle line, which is nearest to the plane of E.F., is spoken of as the *left point* of the lesser curvature. It was necessary to decide upon some such point, as in some cases the lesser curvature passes perpendicularly downwards for some centimetres at its maximum distance from the middle line.

In those cases in which the pylorus was to the left of the middle line, the figures relating to the lesser curvature in the middle line refer to the upper border of the first part of the duodenum. The summit of the stomach was taken as the highest part of the greater curvature when *in situ*. If the stomach be removed from the body and distended, that part which was the highest when in the body is sometimes found to be, now, below the highest part of the freed organ—the actual summit being previously directed backwards. The part along the highest part of the stomach, *in situ*, which was nearest to the middle line is the one referred to in the Table.

The point along the line of the maximum extent to the left of the stomach, which is nearest to E.F., is spoken of as the *left point* of the greater curvature. The part spoken of as the *right extremity* of the stomach was nearly always the lower border of the pylorus, but in those cases in which the stomach bulged to the right beyond the pylorus, it is taken as the most extreme point to the right which is the nearest to E.F.

AVERAGE POSITION OF THE STOMACH.

The lesser curvature.—The average width of the cardiac orifice was a little over 2 cm. Its central point was situated 2.1 cm. below the infra-sternal notch, and 7.7 cm. above E.F.; 1 cm. from the middle line.

Traced from the cardiac orifice, the *lesser curvature* passed downwards and to the left until it reached its 'left point' a little over half way between the infra-sternal notch and E.F., at a distance of 3.8 cm. from the middle line. This 'point' was 4.5 cm.

above E.F., and 5.3 cm. below the infra-sternal notch. From this left point the lesser curvature turned inwards and downwards to the middle line, which it reached at a point 1.9 cm. above E.F., or 7.9 below the infra-sternal notch. From this point the lesser curvature passed for 2 cm. to the right of the middle line, inclining a little downwards to the pylorus. The average level of the upper border of the pylorus above E.F. was .76 cm.

In connection with the fall in level of the lesser curvature from the middle line to the pylorus, it should be pointed out that if the 4 cases in which the stomach was displaced very low down in the middle line be excluded, in the remaining 36 cases—90 per cent. of the entire series—the fall of the lesser curvature from the middle line to the pylorus was very small indeed, being only .15 cm.; the level of the upper border of the pylorus in this 90 per cent. of cases being exactly 1.75 cm. above E.F.

The greater curvature.—Passing along the greater curvature from the cardiac orifice, the stomach reached its maximum height in the upper part of the 5th intercostal space at a distance of 5.1 cm. from the middle line, and .13 cm. below the infra-sternal notch, and 9.66 cm. above E.F. Continuing to the left, the greater curvature maintained nearly this level for a further 3 cm., extending to about 8 cm. from the middle line. It then turned downwards in the concavity of the diaphragm, extending still more to the left as far as its 'left point,' which was situated at a distance of 10.7 cm. from the middle line, 3.5 above E.F., whence it turned inwards as the lower border of the stomach. It emerged from beneath the costal arch, at the 9th costal cartilage, a very little below the plane of E.F. (.5 cm.), and continued inwards, with a slight convexity downwards, to the middle line, which it reached at a point 2.5 cm. below E.F. The average width of the stomach, therefore, over the middle line was 4.4 cm., and the line E.F. passed about midway between its upper and lower borders, being, as a matter of fact, .3 cm. above the middle.

From the middle line the greater curvature passed to the right for 2.8 cm., with an inclination upwards; its right extremity being situated 1.75 cm. below E.F. The pylorus had a vertical

depth of 2·5 cm., its upper border being situated 2 cm. and its lower border 2·8 cm. from the middle line; the line of the orifice thus passed obliquely downwards and to the right, and the line E.F. passed almost midway across it,—as a matter of fact, a little nearer its upper than its lower border.

The remarkable regularity of the line E.F., as a guide to the pylorus, the stomach in the middle line, and, with less accuracy, the greater curvature in the left lateral line, seems to give it a very considerable value as a surface-line. These points are seen at a glance on reference to fig. 4, in which all the stomachs are displayed on the one-ninth scale, arranged along vertical and horizontal lines representing the middle line and E.F. respectively. It will be seen that in at least 29, or 72·5 per cent., of the 40 cases, E.F. as a guide line to the pylorus would have been absolutely reliable.

From the foregoing figures it may be pointed out:—

That the average transverse width of the stomach, as seen from the front, at the level of the 'left point' of the lesser curvature, was 7 cm.; that the vertical depth at the point where the greater curvature passes from the costal margin, a little below the level of E.F., was 10 cm.; that the distance on the vertical plane from the centre of the cardiac orifice to the centre of the pylorus was 8·2 cm.; that the distance between the lower border of the cardiac orifice and the upper border of the pylorus in the vertical plane was 5·9 cm.; and that the distance on a transverse plane between the centres of the two openings was 3·5 cm. The accordance, or otherwise, of any of these averages with the surface markings generally adopted will be referred to in discussing the variations in the position of the stomach.

To summarise the foregoing statement in general terms of inches:—

The central point of the cardiac orifice is situated rather less than an inch below the infra-sternal notch, about half an inch from the middle line. From the cardiac orifice the lesser curvature passes downwards and to the left, until it reaches a point rather more than half way from the infra-sternal notch to E.F., at a distance of $1\frac{1}{2}$ inches from the middle line. Here it bends inwards and downwards, and reaches the middle line about $\frac{3}{4}$ of an inch above E.F., beyond which it continues to the

right for nearly an inch, to end as the upper border of the pylorus.

The greater curvature, from the cardiac orifice, passes outwards and upwards until the stomach attains its maximum height in the 5th interspace in the left lateral line, about the level of the infra-sternal notch. The greater curvature continues for rather more than an inch further outwards in this level, where it bends downwards, gradually attaining a maximum distance of nearly $4\frac{1}{2}$ inches from the middle line. At this maximum distance from the middle line, under cover of the ribs, it reaches a point $1\frac{1}{2}$ inches above the level of E.F., where it bends inwards, forming the lower border of the stomach which passes from beneath the costal arch about the level of E.F., a little behind the tip of the 9th costal cartilage. From this place the greater curvature continues inwards with a slight convexity downwards, reaching the middle line 1 inch below E.F., from which it passes to the right, with a slight inclination upwards for a little over an inch, to the lower border of the pylorus.

The pylorus is situated 1 inch to the right of the middle line, and is bisected by the line E.F.; its upper border is 3 inches below the infra-sternal notch.

The line E.F., beside bisecting the pylorus, practically bisects the portion of the stomach overlying the middle line, and represents the lower border of the stomach, where it meets the left costal arch.

The distance on a vertical plane between the centres of the cardiac and pyloric orifices is about 3 inches, and on a transverse plane nearly $1\frac{1}{2}$ inches.

DESCRIPTION OF PLATES XLIII. AND XLIV.,

REFERRED TO, ERRONEOUSLY, ON pp. 582 AND 585 AS FIG. 4.

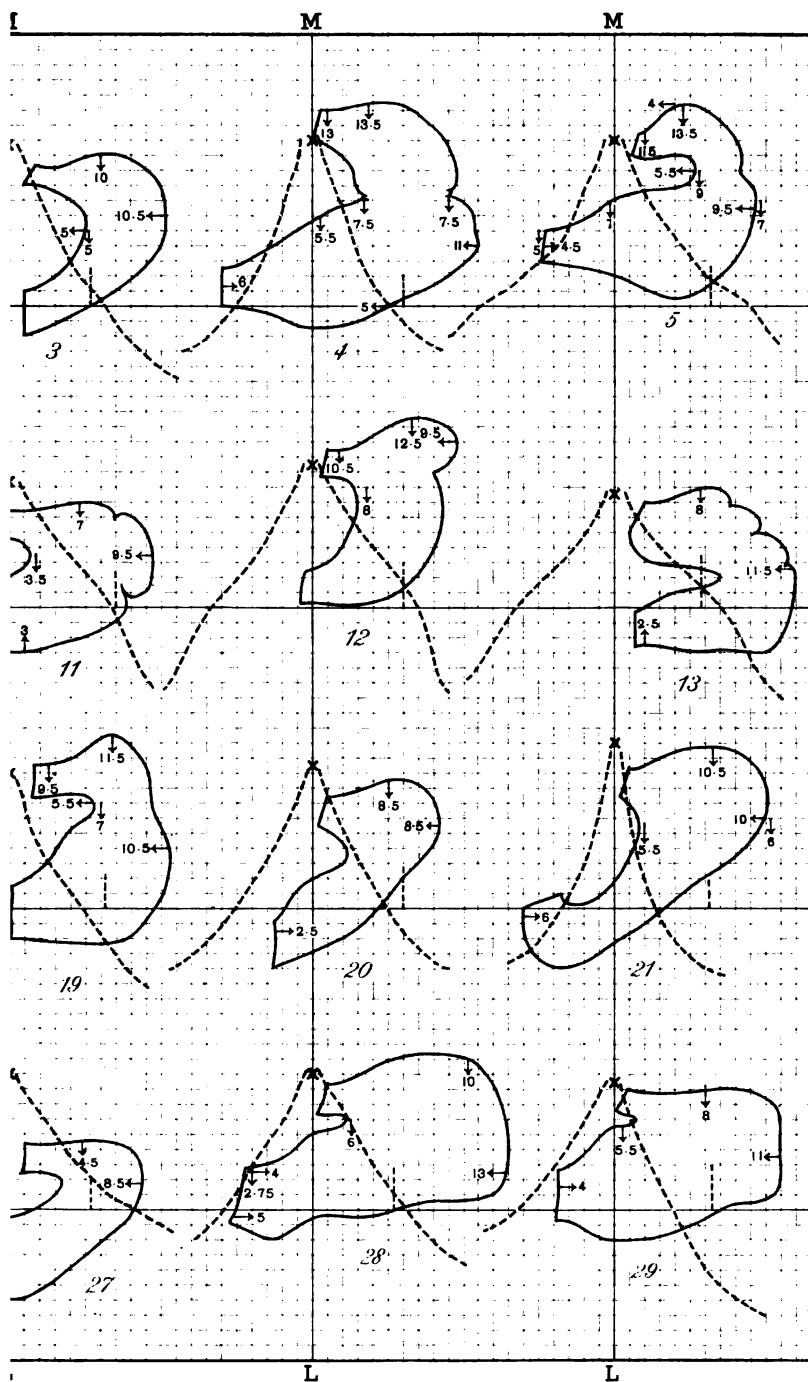
Figures showing the stomachs from the whole series of cases, arranged on a scale of one-fifth—the divisions representing centimetres—about the middle line (M.L.) and the upper transverse abdominal line (E.F.). The costal arch and the position of the left lateral line are also represented.

To follow page 586.]

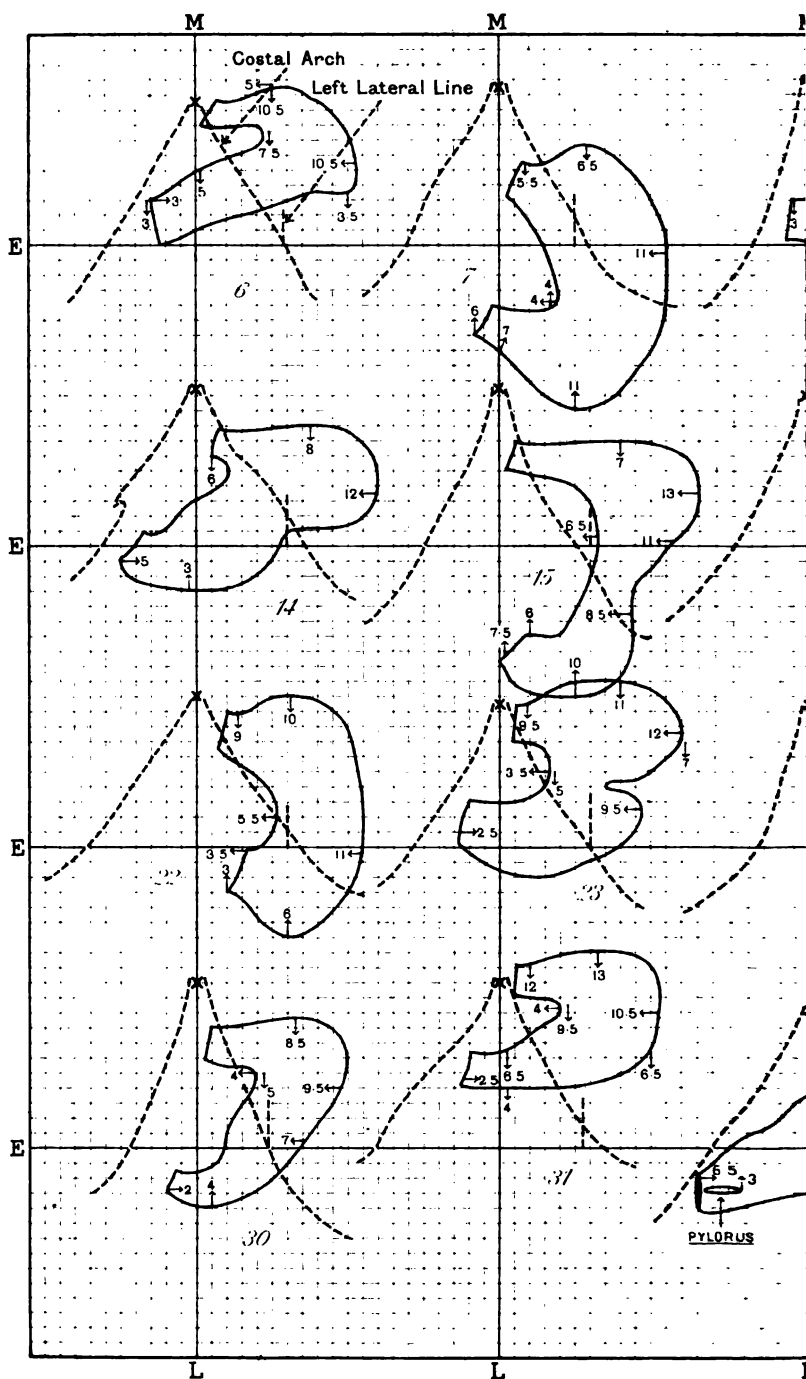
All measurements in centimetres except the height, which is in feet and inches.
The sign = indicates corresponding points or levels.

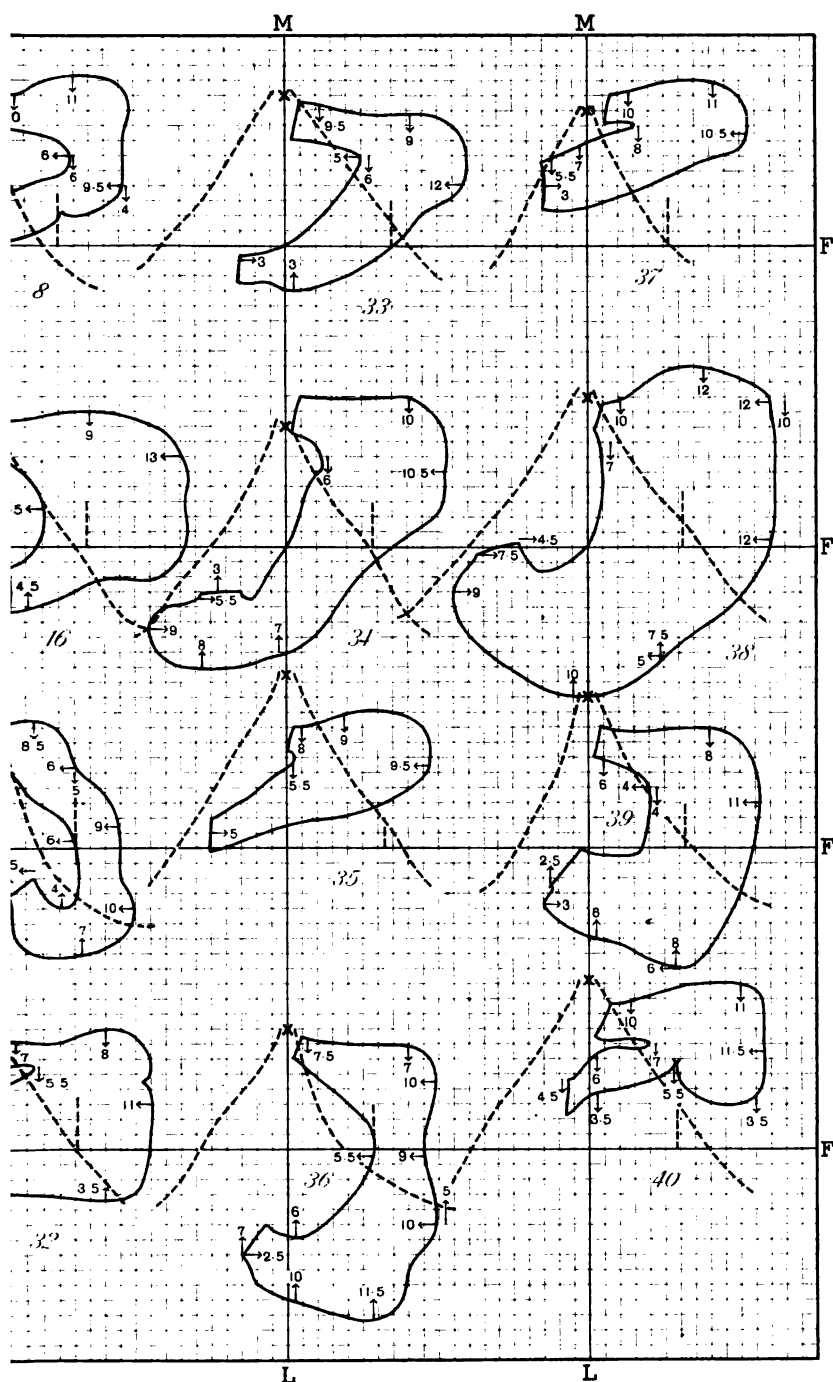
NOTES.	NUMBER OF CASE.
	Age, . . .
	Sex, . . .
	Height, . . .
	Distance from the upper border of the pubes to the supra-sternal notch, .
(1)	„ between the transverse abdominal lines C.D. and E.F., .
	„ of the infra-sternal notch below the transverse thoracic line X.Y., .
	„ „ „ „ above E.F., .
	„ „ sacral promontory . below C.D., .
	„ „ anterior superior iliac spine „ C.D., .
	„ „ umbilicus . . . above C.D., .
	„ „ aortic bifurcation . . „ C.D., .
	„ „ highest part of the iliac crest „ C.D., .
(2)	„ along the lateral line to the <i>costal arch</i> —right, .
	„ „ „ „ „ left, .
	„ from the ant. sup. iliac spine to the <i>costal arch</i> —right, .
	„ „ „ „ „ „ left, .
	„ „ highest part of the iliac crest to the <i>costal arch</i> —right, .
	„ „ „ „ „ „ left, .
	„ between the anterior superior iliac spines, .
(3)	„ of the <i>lateral lines</i> from the <i>middle line</i> , .
	Width of the body . in the plane of C.D., .
	„ „ „ „ E.F., .
	„ across the <i>costal arch</i> „ E.F., .
(4)	The <i>costal cartilage</i> cut by E.F.—right, .
	„ „ „ E.F.—left, .
	The point where the lateral line cuts the <i>costal arch</i> above (a) } —right,
	or below (b) the plane of E.F., } —left,
	The plane E.F. above (a) or below (b) the disc between 1 st and 2 nd vertebrae,
(5)	Commencement of examination. Hours after death, .
(6)	Condition of nutrition, .
(7)	Place of examination, .











ON THE CEREBELLUM OF THE HORSE. By O. CHARNOCK BRADLEY, *Lecturer on Anatomy, New Veterinary College, Edinburgh.*

ALTHOUGH no mammal, excepting man himself, is so frequently and carefully dissected as the horse, the equine cerebellum has received little attention at the hands of anatomists. The English text-books on Veterinary Anatomy contain very elementary descriptions of this organ; no attempts being made to distinguish individual parts other than the fundamental ones of vermis and hemispheres. The continental works are only a degree more detailed. The latest German work, however—that of Ellenberger and Baum¹—has made a distinct advance. Here it is sought to divide the cerebellum into parts corresponding to those recognised in the human brain. Unfortunately these authors have not been entirely successful in their application of nomenclature. *Three* lobes are described and figured under the names of Monticulus, Culmen, and Declive. The result of this is the slumping together of the folium cacuminis and tuber valvulæ, and the statement that the nodule is very rudimentary. Although these and some statements of minor import can hardly be taken as correct, still the thanks of comparative anatomists in general, and veterinary anatomists in particular, are due to these painstaking and deservedly eminent investigators.

Numerous writers, at different times and in various languages, have given, if not detailed descriptions, at least noteworthy illustrations, which well merit careful examination by anyone working upon the mammalian cerebellum.

The famous atlas of Leuret² contains figures of the horse's cerebellum from two points of view, as well as a representation of a sagittal section passing through the middle of the vermis. Excellent as these figures are, and fulfilling,—as was no doubt the intention of the author—the purpose of giving a general idea of the organ, they, nevertheless, fail to demonstrate various

¹ *Anatomie des Pferdes*, 1894.

² *Anatomie comparée du Système Nerveux*, 1839-57.

lobes: this, probably, because the author himself did not recognise these lobes as such.

Other and more recent works, such, for instance, as that of Chauveau,¹ give a fairly accurate notion of the appearance presented by sections through the vermis and hemispheres, but are misleading in their interpretation of the external anatomy.

A short paper by Bert Brenette Stroud² contains an implied promise of a further contribution, which shall deal with the cerebellum of the horse, as well as those of many other mammals. I have not been able to discover that the promise so implied has been kept; therefore little help is forthcoming from this source.

It would serve no good purpose to enumerate several other publications which have touched more or less upon this subject. It may be stated, therefore, that little has been written concerning the more detailed anatomy of the horse's cerebellum; and that, in consequence, there is still room for investigation.

For some time past I have made notes of the various cerebella used in ordinary class work, and these notes have been supplemented by the dissection of six cerebella, specially prepared for

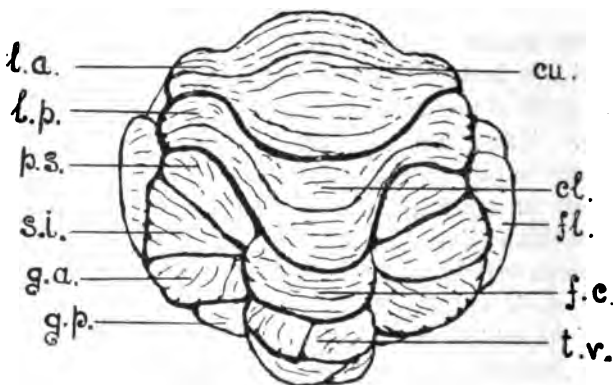


FIG. 1.—View of the superior surface of the horse's cerebellum.

this purpose. In the following account the results are set forth, and although, in the light of further research, emendations will possibly require to be made, it may be taken that the conclusions have been arrived at after careful inquiry and comparison.

¹ *Anatomie Comparée des Animaux domestiques*, 4^{me}, edit. 1890.

² "The Mammalian Cerebellum," *Journ. of Comparative Neurology*, vol. v., 1895, p. 71.

VERMIS.

Fundamentally, the vermis of the horse's cerebellum agrees with that of man. The same parts may be readily recognised, the differences being those of detail only.

The *lingula* consists of a variable number (generally about five or six) of transverse folia. In a large proportion of specimens, one or more folia are so developed in a lateral direction as to appear to be prolonged into the lateral hemisphere. This was the case on both sides in two cases out of six, in three cases the prolongation was unilateral, while in the remaining

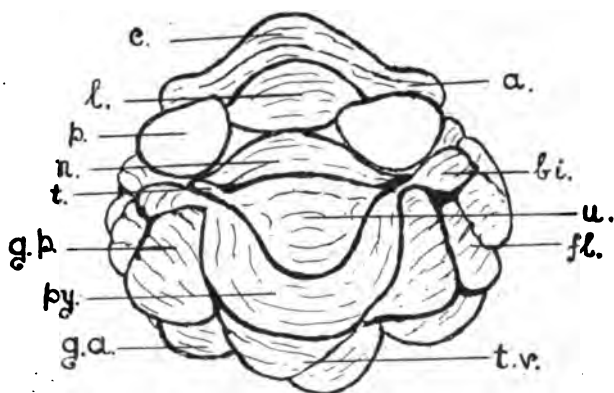


FIG. 2. — Inferior surface of the horse's cerebellum.

specimen no prolongation was evident. The connection of the lingula with the anterior medullary velum is only very limited.

The *lobulus centralis* is larger than the lingula, and has its surface indented by either one or two deep transverse sulci. In three specimens the sulci were two in number; in the other three cases only one fissure was present. If one fissure alone be present (and this, I am inclined to think, is most commonly the case), it divides the lobe into two almost equal parts, and is continued into the alæ.

The *culmen monticuli* is most commonly the largest lobe of the vermis. As a rule, three transverse sulci cross its superficial surface. The middle sulcus is always the deepest and most

constant; it is prolonged laterally into the lobus lunatus anterior.

The *clivus monticuli* always forms a smaller part of the vermis than the culmen. A constant, deep transverse fissure divides it into two equal, or nearly equal, parts. This fissure, like those of the culmen and lobulus centralis, implicates the lateral hemisphere.

The *folium cacuminis* and *tuber valvulae* are not separated from each other by so deep a sulcus as are the other lobes of the vermis. On this account a casual examination might lead to



FIG. 3.—Posterior view of the horse's cerebellum.

the conclusion that they are blended. This probably accounts for the fact that Ellenberger and Baum¹ have described them as constituting a single lobe under the name 'declive.'

The *folium cacuminis* is relatively large, and consists superficially of four or five transverse folia.

An oblique fissure, running invariably downwards from right to left, divides the *tuber valvulae* into right and left portions, each of which carries several oblique folia on its superficial surface.

The *pyramis* frequently attains a considerable size, being, in the majority of instances, much larger than either the *uvula* or the *nodulus*. On examination of its superficial surface, a transverse fissure of variable depth will be found.

The *uvula* possesses either one or two transverse fissures.

The *nodulus*, always somewhat smaller than the *lingula*, is never so small as the description given by Ellenberger and Baum would lead one to imagine. These authors state that it

¹ *Op cit.*

is joined to the uvula, and can only be made out by a good sagittal section. It is obvious that their description applies to something else which they are led to consider as the nodulus by their somewhat peculiar use of the terms applied to the various lobes of the vermis.

LATERAL HEMISPHERES.

As has been pointed out above, one or more folia of the lingula may be so developed in a lateral direction as to exceed the limits of the vermis, and thus encroach upon one or both hemispheres.

The *ala lobuli centralis* are always small,—indeed, in some specimens they may be absent on one side. As a rule, however,

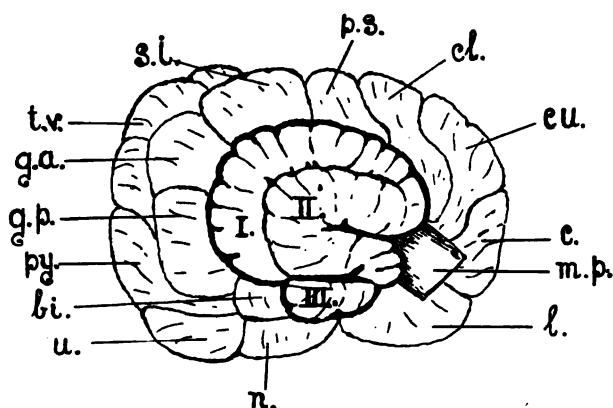


FIG. 4.—Right lateral view of the horse's cerebellum.

they exist as two rounded eminences on each side of the cerebellum. Between the two eminences is the continuation of the deep transverse fissure of the lobulus centralis.

Both the *lobus lunatus anterior* and the *lobus lunatus posterior* must be considered as being relatively small in comparison with the corresponding lobes in man. The latter lobe is generally somewhat the larger. They are connected by broad and conspicuous folia-bearing bands with the culmen and clivus respectively, and have their surfaces marked by fissures continued from these lobes of the vermis.

The *lobus postero-superior* occupies an oblique position on a level with the clivus. In size it does not attain any marked development, nor are its oblique folia very numerous. An intimate connection with the folium cacuminis is easily demonstrable; but, as will be shown immediately, the lobi semilunaris inferior and gracilis anterior share in this connection with the vermis.

The *lobus semilunaris inferior* appears on the surface of the hemisphere as a triangular lobe, with its apex in contact with the folium cacuminis. Its size always exceeds that of the lobus

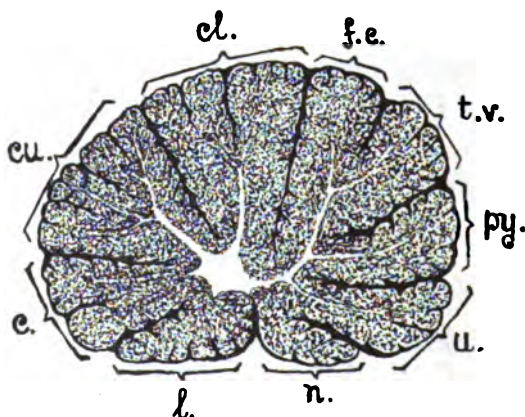


FIG. 5.—Sagittal section through the middle of the vermis; viewed from the left.

postero-superior. The common connecting band referred to above joins it to both the folium cacuminis and the tuber valvulæ.

There is no difficulty in distinguishing the *lobulus gracilis anterior* from the lobus semilunaris inferior, because the folia of the former run obliquely backwards and outwards, whereas those of the latter pass forwards and outwards. The lobulus gracilis anterior is the third of the three lobes sharing in the common connecting band which passes from the hemisphere to the folium cacuminis and tuber valvulæ.

The *lobulus gracilis posterior* is slightly larger than the gracilis anterior. A narrow band connects it with the tuber valvulæ, but is in no way blended with the broad band mentioned in the immediately preceding paragraphs.

It might be as well, perhaps, to shortly summarise the connections of the postero-superior, inferior semilunar, and anterior and posterior gracile lobes with the vermis, as follows:—The postero-inferior, inferior semilunar, and anterior gracile lobes share in a common band; but the postero-superior lobe is joined to the folium cacuminis only, whereas the two remaining lobes are connected with both folium cacuminis and tuber valvulæ. The posterior gracile lobe is associated with the tuber valvulæ only, and this by means of a separate band.

The *lobus biventralis* is always small, and connected with the pyramis by a low but distinct band.

In the majority of specimens the *tonsil* is either entirely absent or, if present, very small. In one specimen only (out of

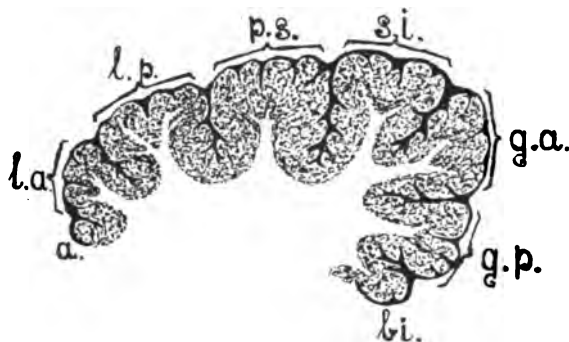


FIG. 6.—Sagittal section through the middle of the right lateral hemisphere.

six) was it present on both sides. In another specimen it was developed on one side only, while in the remaining four specimens no traces were discoverable. When present, its connection with the uvula is easily shown, but the band is never furrowed, as in man.

A large *flocculus*, separated from the rest of the hemisphere by a deep fissure, into the depth of which the middle cerebellar peduncle can be traced, completes the cerebellum. Its size and arrangement differ considerably from that of the flocculus of the human cerebellum, but agree very closely with that of the cat as described and figured by Stroud.¹ A small lower portion (fig. 4, III.) in contact with the biventer lobe is surmounted by two large curved portions. Stroud has applied the name of

¹ *Op. cit.*

paraflocculus to these more conspicuous parts. The upper and larger he calls the supraflocculus (fig. 4, I.); the lower, the mediflocculus (fig. 4, II.); reserving the term flocculus for the small underlying fragment (fig. 4, III.), for the reason, apparently, that he considers this, and this alone, to correspond to the human flocculus.

The paraflocculus may represent the 'accessory flocculi' of human anatomy. Whatever may be the correct interpretation, the disposition is constant, and the posterior medullary velum is connected with that part marked III. in the figure. Stroud further suggests names for the sulci, separating the three parts of the flocculus from each other and the entire flocculus from the rest of the hemisphere. The infrafloccular sulcus separates the lobe into its individual parts, while the parafloccular sulcus distinguishes the lobe from the other parts of the hemisphere.

ARBOR VITÆ CEREBELLI.

A sagittal section through the vermis reveals a corpus trapezoides, so placed that its posterior limit is on a level with the pointed tip of the 'tent' of the fourth ventricle.

From this central mass of white matter three chief branches take origin. The most anterior passes into the culmen monticuli. The second branch, almost vertical in direction, forms the white core of the clivus monticuli. The most posterior branch contributes small secondary branches to the nodule and uvula; a much larger branch is lost in the pyramis; and finally, a bifurcation provides white matter for the folium cacuminis and tuber valvulæ. The lingula and lobulus centralis derive their white matter directly from the corpus trapezoides.

In sagittal sections through the middle of the lateral hemisphere the white matter has a simpler arrangement. From the large corpus trapezoides, separate and thick branches proceed to the lobus lunatus anterior, lobus lunatus posterior, lobus postero-superior, and lobulus gracilis posterior. A thicker and more conspicuous ramus bifurcates and terminates in the lobus semilunaris inferior and lobulus gracilis anterior.

Two small processes are contributed to the ala lobuli centralis and lobus biventralis.

SULCI.

In the following table the depths of the sulci are given in millimetres.

The tonsil is so frequently absent that no definite conclusion could be arrived at as to the depth of the sulci associated with it. It will probably never be greater than 2 mm.

VERMIS.		HEMISPHERE.
Lingula,		
11 mm.	<i>Sulcus precentralis.</i>	
Lobulus centralis,		Ala lobuli centralis.
15 mm.	<i>Sulcus postcentralis.</i>	5-6 mm.
Culmen monticuli,		Lobus lunatus anterior.
19-20 mm.	<i>Sulcus preclivalis.</i>	7-8 mm.
Clivus monticuli,		Lobus lunatus posterior.
24-25 mm.	<i>Sulcus postclivalis.</i>	10 mm.
Folium cacuminis,		Lobus postero-superior.
10 mm.	<i>Sulcus horizontalis magnus.</i>	12 mm.
Tuber valvulæ,		Lobus semilunaris inferior.
	<i>Sulcus postgracilis.</i>	11 mm.
		Lobulus gracilis anterior.
	<i>Sulcus intragracilis.</i>	12-13 mm.
		Lobulus gracilis posterior.
16 mm.	<i>Sulcus pregracilis or postpyramidalis.</i>	7 mm.
Pyramis,		Lobus biventralis.
18 mm.	<i>Sulcus prepyramidalis.</i>	
Uvula,		Amygdala.
10 mm.	<i>Sulcus postnodularis.</i>	
Nodulus.		Flocculus.

EXPLANATION OF FIGURES IN TEXT.

l., lingula; *c.*, lobulus centralis; *cu.*, culmen monticuli; *cl.*, clivus monticuli; *f.c.*, folium cacuminis; *t.v.*, tuber valvulæ; *py.*, pyramis; *u.*, uvula; *n.*, nodulus; *a.*, ala lobuli centralis; *l.a.*, lobus lunatus anterior; *l.p.*, lobus lunatus posterior; *p.s.*, lobus postero-superior; *s.i.*, lobus semilunaris inferior; *g.a.*, lobulus gracilis anterior; *g.p.*, lobulus gracilis posterior; *bi.*, lobus biventralis; *f.*, flocculus; *p.*, cerebellar peduncles; *m.p.*, middle cerebellar peduncle. I. II. III. (in fig. 4), the three parts of the flocculus.

ON THE POST-EMBRYONAL HISTORY OF VOLUNTARY
MUSCLES IN MAMMALS. By ALEXANDER MEEK, M.Sc.,
F.Z.S., *Durham College of Science, Newcastle-upon-Tyne.*

IN this paper I propose giving the results of my enquiries into the changes which take place in skeletal muscle during growth, with such thoughts as naturally arise from these results, but without entering into the general considerations of post-embryonal development. The research was undertaken, as stated in a preliminary note,¹ with the simple view of showing what share hyperplasia and hypertrophy took in the evolution of the muscle in the individual. Since the preliminary communication was written, I have been able to extend the number of stages and types, and to add others, which shed some light on the influence of sex, of variation, and of habit in modifying the development.

(1) METHODS.

After some consideration as to the best method of approaching the problem, I determined to take the middle part of the hardened muscle—usually the middle third—to cut this into a series of transverse sections, and to attempt to count the fibres occurring in a typical section. Many stains were employed, but I found that the best results were got by staining in bulk in borax carmine and differentiating in acid alcohol. As very thin sections were not desirable, it was always possible, even with the later stages, to get complete sections. In some cases, after decalcifying, the whole limb was cut across, but this was generally found to be an unsatisfactory process.

The fibres were counted, with a convenient power in each case, with the aid of an eye-piece micrometer ruled in squares. As each square was counted, the number of fibres was written on a sheet of paper, similarly ruled in squares; the position of the square being counted, and the corresponding one on the paper could always in this way be localised. In some cases, where a

¹ *Anat. Anz.*, 1898, Bd. xiv. No. 24.

large number of fibres occurred, impossible to count in a reasonable time, and also as a control to actual enumeration, a fairly large number of squares was actually counted, and the average number thus obtained was multiplied by the number of squares covered by the section. Still another method was employed for the larger sections. The average number of fibres (a) was found, as above, with one power; the side of the square was carefully measured (b); the whole area covered with a lower power was noted (d); the side of the square being again carefully measured (c). It was easy then to find the approximate number of fibres by calculating as follows:— $a \times \frac{c^2}{b^2} \times d = no.$

By using different combinations of powers, it was found that the resulting numbers did not differ among themselves to such an extent as to interfere with the desired contrast between the stages.

(2) MATERIAL AND RESULTS.

I shall now present in detail the results obtained by these methods, pointing out in each case how the results have been obtained.

The animals chosen were—

(a) *Young and Adult of the Field Vole (Arvicola agrestis).*

These were obtained on the same day in a hay-field at Wingate Moor, in Northumberland—the young from the nest, and a pregnant female, furnishing the two stages.

Left Triceps.

	No. of Fibres.	Aver. p. sq. of 151 mm.	Area of Sect.— mm.	Aver. area of Fibre.— mm.	Percent- age of Fibres.
Young male, ...	10,070 ...	114 ...	1.95 ...	0.0002 ...	100
Adult female, ...	4,613 ...	17 ...	4.96 ...	0.0013 ...	46

Left Sterno-Mastoid.

Young male, ...	2,696
Adult female, ...	1,128

Right Sterno-Mastoid.

Young male, ...	2,596 ...	131 ...	0.4389 ...	0.00017 ...	100
Adult female, ...	2,110 ...	37 ...	1.2426 ...	0.0006 ...	81

External Measurements of the Two Stages.

	Head.		Body.		Tail.
Young male, ...	1.8 cm.	...	4.5 cm.	...	1.3 cm.
Adult female, ...	3.0 "	...	9.0 "	...	4.0 "

The number of fibres was obtained in each case by enumeration. The results for the triceps were published in the preliminary paper, and in preparing this paper a rapid calculation in the manner described above gave for the young 10,614, for the adult 3,912. Widely different sections of the series in each case were used for this re-determination.

With regard to the right sterno-mastoid, one counting of the young condition gave 2,596, another 2,420; one calculation 2,669, another 2,539: the first number is taken. The number for the adult muscle as counted was 2,110, as calculated 2,116.

The left sterno-mastoid results I have not extended as in the case of the others, for there was a large invasion of connective tissue in the adult condition.

In both these muscles of the field vole "*hypertrophy of the fibres occurs accompanied by a reduction in their number*,"¹ a result which we need not dwell upon until we see what the other examples show. One is struck, however, even in the case of this one animal, with the numbers, which seem to point to a survival amongst the fibres affecting the triceps to such a large extent, and the sterno-mastoid to only a slight degree. The relative positions of the two muscles at once suggests that the conditions which would give rise to a survival of the fittest elements at the expense of the others—if one may use still the term "survival of the fittest"—would affect the triceps much more than the sterno-mastoid.

The numbers for the latter muscle, moreover, seem to show that in the young condition, or newly-born, the fibres are much the same in number on both sides of the body, but during extra-uterine life the competition among the elements does not affect both sides of the body to the same extent.

¹ Preliminary paper, *loc. cit.*

A word may be added with regard to the fasciculi. In the young stage of the triceps they are irregular in size, but on the whole comparatively large, more closely packed together externally, but loose on the internal side of the muscle. In section they are triangular, strap-shaped, or fusiform. In the adult there is practically no change in appearance; the fasciculi are larger, presenting a less number of fibres, and answer otherwise to the general description given above. The sternomastoid is very similar, but there are fewer fasciculi in the section. The muscle as a whole seems to fall into three distinct areas, which appears to show that it may be a compound one.

The other numbers in the table are self-explanatory. It is necessary to state, however, that the "area of the fibre" was got by dividing the average number per square into the area of the square, and it thus includes its share of the "between space."

(b) *The Cat* (*Felis domestica*).

The following numbers were obtained in a similar examination of the biceps of the cat. The first three stages all belonged to the same litter, but the last one was obtained from the Newcastle Dog and Cat Shelter. I was assured that the cat was at least 3 years old, and its appearance and the condition of the teeth confirmed this statement. The 240 days old member of the family which furnished the first three stages is interesting, moreover, in that she had just reached the stage of the first ovulation.

Left Biceps.¹

Age.	Sex.	Number of Fibres.	Aver. p. sq. of ·0263 mm.	Area of Sect.— mm.	Area of Fibre— mm.	Percentage of Fibres.
9 days	... Male	... 83,514	... 7·0	... 8·4	... 0·0001	... 100
20 days	... Male	... 64,108	... 5·5	... 8·1	... 0·00013	... 77
240 days	... Female	... 37,830	... 1·15	... 22·8	... 0·0006	... 45
3 years or more	... Male	... 22,858	... 0·34	... 46·8	... 0·0021	... 27

The diminution in the number of fibres evidenced in the field vole is more than confirmed in the case of the cat. In spite of

¹ See note, p. 608.

the large increase in the size of the muscle as a whole, the number of fibres has diminished to nearly a fourth, if we compare the first stage with the last. That the growth of the muscle is always characterised by regression in the number of fibres to this extent I do not wish to affirm, but that a distinct regression occurs during the post-embryonal history of this particular muscle is quite certain.

The numbers were obtained by making calculations in the manner already described. This was done repeatedly with different groups of powers, and the numbers given are the averages of the results.

In section, the biceps of the cat presents numerous small fasciculi. Muscle spindles seen also in the biceps of the field vole are more common here (*cf.* p. 603). In the second stage the fasciculi do not appear to be any less numerous than in the first, but they include a smaller number of fibres. In stage three the fasciculi appear to become rearranged into groups, which doubtless determine the fasciculi of the adult.

(c) *The Sheep (Ovis aries).—One of the Outer Heads of the Perforans.*

Age.	Sex.	Number of Fibres.	Average p. sq. of 0263.	Area of Section. mm.	Area of Fibre. mm.	Proportion of Fibres.
Embryo, ...	♀ ...	29,174 ...	10·5 ...	1·916 ...	·00007 ...	42
2-3 weeks, ...	♂ (?) ...	69,694 ...	4·0 ...	12·057 ...	·00017 ...	100
6 months (?) ...	♂ (?) ...	81,978 ...	1·0 ...	22·117 ...	·00069 ...	46

The embryo was a late (aborted) one, given me some years ago by a student. The 2-3 weeks' specimen I received from the North Tyne district during the time I was engaged investigating the cause of louping-ill. The last stage I got for comparison from a local butcher. The muscle chosen was the inner of the two outer heads of the flexor pedis perforans, and the part cut into sections was taken as nearly as possible at the same level—a little above the right carpus in each case.

The numbers given in the table are borne out by a further determination of both the outer heads of the same muscle. For the first two stages the embryo presented 59,622, and the 2-3 weeks' 135,483 fibres. The results were got by calculation,

and are the averages of several trials, with different combinations of powers for each stage.

The figures serve to show that it is somewhere about birth that the process of development by hyperplasia comes to an end, and, compared with what has already been set forth, they further indicate that post-embryonal life brings about a competition amongst the fibres, the result of which is expressed in a survival of certain of the elements at the expense of their less fortunate neighbours.

(d) *Tame Rat* (*Mus rattus*).

The common white rat was also examined, as reported on in the preliminary communication. In the case of the flexor longus digitorum, with which is associated the flexor longus pollicis,¹ the number of fibres at two days was found to be 3020, and at forty-seven days 2275.

Morpurgo,² however, seems to have found in the *m. radialis* (?) of the tame rat that a slight accretion in the number of fibres takes place after birth. I have not yet met with an exception such as this to the conditions I have already attempted to demonstrate; but if it does occur, it would most likely be in an animal of this kind, born in a comparatively imperfect and helpless condition.

Sections were made of the hind legs of three rats chosen from a series kept for breeding purposes in the College garden, and an enumeration in the fibres was made in the case of the

Tibialis anticus.

Parentage.	Sex.	Age.	Number of Fibres.	Length of		
				Head.	Body.	Tail.
		Days.		mm.	mm.	mm.
(1) Tame white ♀ ,, mottled ♂	} ... Male,	... 28 ...	13,066 ...	35 ...	65 ...	67
(2) Tame white ♀ Half-bred ♂						
	... Female,	... 33 ...	9,300 ...	32 ...	57 ...	63
(3) Tame mottled ♀ ,, ,, ♂	} ... Male,	... 35 ...	7,649 ...	35 ...	57 ...	70

¹ Parsons, *P. Z. S.*, 1894, p. 266.

² *Anat. Anz.*, 1898, Bd. xv. p. 200.

The 'half-bred' male was derived from an ordinary wild male crossed with a tame female rat. His progeny shows still how strongly prepotent the wild male is over the tame rat, but these results will be referred to in another paper. The history of the muscular tissue, however, does not seem to have been greatly, if any, altered with this parentage.

All these results pointing to a gradual reduction in the number of fibres in the case at least of many, if not all, skeletal muscles, it seemed desirable to compare one muscle from a number of young animals from the same litter, and of the same age. The following calculations refer to four kittens which answer to this description. They were 2-3 weeks old, and the mother of these is also the mother of the first three stages recorded on p. 599:—

Biceps of Kittens of same Age.

	Left.		Right.
Male,	51,504 . . .		53,573
Male,	59,546 . . .		48,056
Male,	55,774 . . .		48,874
Female,	46,454 . . .		43,935
	Average, 53,320.		Average, 48,640.

In the case of the left side, the muscles were kept separate, and are tabulated accordingly; on the right side the muscles were all put into the same bottle, and the numbers, though written in line with the others, do not, of course, correspond. I think I have, however, separated them into male and female, for the last number is almost, if not quite, distinctive.

Without laying too much stress upon such a small series, the results show—(1) that in this case the right presents relatively smaller numbers; that at any rate the conditions of extra-uterine life do not affect both sides of the body to the same degree (*cf.* the figures for the field vole on p. 597); (2) variation occurs in the number of fibres at the same age in individuals belonging to the same family; that this variation increases with age has already been indicated in the results for the field vole referred to above; and (3) that the number of fibres is less in the female than in the male at the same age.

Having thus found that during extra-uterine life the growth of voluntary muscles is characterised by a decrease in the number of fibres accompanying an individual increase in the size of the surviving fibres, it becomes necessary to try to indicate—

(3) WHAT BECOMES OF THE FIBRES WHICH DISAPPEAR.

One naturally turns first to those interesting organs the muscle spindles, the origin and function of which have caused much research and speculation within recent years. These were first distinctly described by Weismann¹ in 1861, in the frog, and since then the literature on the subject has grown into an already large bibliography.

'Muscle spindles,' or 'neuro-muscular organs,' to choose two of the more typical of the many names which have been applied to the structures, are groups of small muscular fibres enclosed in a common sheath, the whole forming a spindle-shaped body. Each is richly supplied with nerves, and receives also blood-vessels and lymphatics. They usually occur singly, but groups of two, three, or even four have been noted.

They are principally found in the muscles of the limbs and the walls of the body, but are said to be absent in the muscles of the eye, the intrinsic muscles of the tongue, and the diaphragm (Batten²). Siemerling,³ however, described a spindle in the atrophied inferior rectus of the eye, and Forster⁴ in the hinder part of the tongue. Fraenkel⁵ says they are absent in the masseter. They appear, from all accounts, nevertheless, to be rare except in the places indicated; they are particularly common in the muscles of the extremities. If this be true, then all muscles do not present them, and therefore they are not essential to a muscle's well-being.

The details of the structure of these organs have been well described by Kerschner,⁶ Ruffini,⁷ and Batten,⁸ and they and others have shown that the tendon organ, or organ of Golgi, is homologous to the muscle spindle.

¹ *Z. f. rat. Med.*, 1861, Bd. x.

² *Arch. f. Psychiatrie*, 1888, Bd. xix.

³ *Virch. Arch.*, 1878.

⁷ *Brain*, 1897, vol. 20.

² *Brain*, 1897, vol. 20, p. 138.

⁴ *Virch. Arch.*, 1894, Bd. 73.

⁶ *Anat. Anz.*, 1893, Bd. viii.

⁸ *Brain*, 1897, vol. 20.

The earlier writers looked upon the organ as a developmental phase of muscle (Weismann, Kölliker, Beale, Kühne), an opinion which has also received support in more recent years, and Bremer even attempted to trace the development. The next explanation which was suggested was that these muscle spindles might be looked upon as atrophied fibres, or were pathological in origin (Fraenkel, Eichorst, Santesson, etc.). But most are agreed nowadays, since the sensory nerve supply was proven by Sherrington, though the fact was just missed by Sachs, that the organ is a sensory one. Kerschner, Ruffini, and others, however, had already given this explanation. Sherrington found that the nerves of the spindles remained intact as well as the spindles themselves in muscles after the motor fibres had been divided, and that the fibres could be traced into the dorsal root.

This led the way to showing that muscles had not only a motor nerve supply, but a complex sensory one distributed to Pacinian bodies, muscle spindles, and tendon organs, and the discovery explained the persistence of such organs in circumstances of disease and experiment leading to atrophy of the ordinary fibres.

Natural as it is, in the light of the facts set forth in the preceding pages, to explain these atrophied-like groups as the disappearing fibres we are looking for, such an hypothesis must be rejected, for the following reasons:—

1. They occur in the foetus (found in 36th week and 4th month foetuses by Felix¹).
2. They appear to share in the degeneration occurring outside them. Felix points out that while the adult spindle presents from 3 to 6 fibres, the foetal spindle may contain as many as 20.
3. The degree of their occurrence in the sections which have come under my observation is far too meagre to account for the reduction I have recorded.
4. The recent facts brought to light regarding them show that they have an important function, or share an important sensory function with the organs mentioned above, perhaps in determining a sense of position and co-ordinating the contractions of groups of muscles.

¹ *Anat. Anz.*, 1888, Bd. ii.

Their origin early in embryonic life from groups of muscle fibres, at first as large as their neighbours, but which do not share in their conspicuous hypertrophy, and their connection with sensory nerve fibres, constitute them remarkable organs, indeed, the origin of which, however, the facts embodied in this paper do not appear to me to throw any light upon whatever. But there will be this relationship between their presence and the conditions I have been describing—they will be found to be most numerous in those muscles in which the reduction in the number of fibres is greatest.

That the fibres fuse together must also be set aside. The proportion of nuclei at different ages has long been known to diminish—for muscular fibres are not only compound in their adult condition, but compound in their origin.¹ This is, of course, because of the immense hypertrophy of the fibre. Morpurgo,² however, has shown that the nuclei retain their proportion to the fibre all the same. They therefore only diminish in number in appearance, and not in fact. Now, if a fusion between fibres took place, a gain in nuclei would be the result.

I therefore do not see any reason for departing from the position I took up in my preliminary communication. We must look upon the fibres as starting with unequal chances: the position of some is more favourable for receiving and acting upon impulses than in the case of others. The former become hypertrophied, while the latter become atrophied, and are ultimately completely absorbed. The inequality is well seen in any section of voluntary muscular tissue, and the effect of mutual pressure in modifying the shape of the fibres has long been known. In the earlier stages, where the competition is keen, the fibres may be observed as of all sizes, from the largest down to mere points.

Such atrophy and regression, from pressure, also occurs in muscles attacked by the parasites of measles and psorospermiosis, and is better known still in other organs liable to parasitic invasion, *e.g.*, the brain of the sheep, containing *Cœnurus cerebralis*, and a liver hollowed out by *Echinococcus*.

¹ *Vide* Morchesini and Ferrari, *Anat. Anz.*, Bd. xi.

² *Anat. Anz.*, 1898, Bd. xv.

(4) HYPER-, HYPO-, AND A-PLASIA.

The changes occurring in voluntary muscle during growth I suggested in my preliminary note could be described as *hypertrophy*, accompanied by *aplasia*. I have since found that hypoplasia or aplasia is used in pathological literature to express the want of a part which should normally have been present. The absence of parts is quite a common pathological phenomenon, but we are just as familiar during development with structures which come into existence, but which have only a transient history, or suffer regression. Without referring to extra embryonal parts, the notochord and the thymus gland may be quoted as well-known examples. It therefore appears to me desirable to distinguish by a word or words between the absence of parts which should have been present, and the total or partial suppression of parts which have been present. I suggest that the word *hypoplasia* should be restricted to the definition of the former condition, and *aplasia* to the latter.

The two processes hypertrophy and aplasia do not affect all muscles to the same degree. The triceps of the field vole presents in the two stages examined (*vide*, p. 597) a reduction of fibres as 100 : 46, while the average hypertrophy, as expressed in the area of the section, has been 2 : 13. The sterno-mastoid of the same animal presents 100 : 81 of fibres at the same stages, while the fibres have hypertrophied from 1·7 to 6. The fibres in the case of the cat (p. 599) decrease in number as 100 : 77 : 45 : 27, while the area of the section of the fibre increases as 1 : 13 : 60 : 210. The large reduction in number, together with the immense hypertrophy, is very apparent in the important muscles of the limbs; whereas, in the case of the sterno-mastoid, the position of which does not call for so much support nor vigour of contraction, the aplasia and hypertrophy are not so marked. It therefore appears that the aplasia and hypertrophy tend to express the functional importance of the muscle.

(5) THE EFFECTS OF HABIT, EXERCISE, ETC.

In this connection comes a question of much importance, to which an answer may be attempted. It is, as to the effects

which exercise—in the case of the athlete—and rest and feeding—from the point of view of the farmer principally—will have in modifying the changes which have been described.

We have seen that the facts appear to show the conditions described above are intensified the more important the muscle. The survival of the fibre, in fact, will be determined by the measure of the contraction, and that by the nervous impulse reaching it and the power of reconverting it. On the other hand, rest and relatively nutritious food must reduce this tendency to select some fibres at the expense of the others, and therefore make the muscle richer in fibres—if the muscle does not reach so high a plane of development. We hear the farmers say that in feeding the best results are obtained by never letting the animal 'lose its calf-flesh.' That is to say, the animal must, by getting suitable food, be kept steadily growing. Relative starvation will necessarily hasten the tendency to atrophy.

The question of 'feeding,' then, from the farmer's point of view, is not one of making more flesh, but rather by observing the rules which practice has so long recommended, of hindering the reduction in the number of fibres, to which all flesh seems to be to a greater or less extent liable.

The development of flesh in the feeding animal and the development of the muscle of the athlete are, in fact, quite opposite in their results.

In the first case, the farmer's aim is to keep as many of the fibres as he can by not exercising too much, and by keeping the blood circulating through the muscles in a rich condition. Nevertheless, the stimulation to the circulation which some degree of exercise gives must not be lost sight of. Covered courts and similar conditions, when confinement is necessary, which admit of the animals moving about freely, seem therefore, with regular feeding, and other considerations of treatment which need not be entered into here, to be the nearest approach to the ideal state of things.

In the case of the athlete, the exercise hastens the choice and development of suitable elements, and the muscle gains in bulk through the hypertrophy of these. It is well-known, moreover, that if the exercise be not kept up, the muscle fibres return to some approach to their old condition, and may even sink beneath

it. Thus the conditions which we have been considering as affecting muscle as a whole, are liable to much variation from external influences. The influence of 'internal secretions' is too well-known to require here more than mention; and it is quite clear, moreover, that the pressure of the fibres upon one another, and its results, will be subject to the influence of the relative pressure of neighbouring muscles and other organs.

To sum up. The life-history of muscle seems to me to be determined by (1) inherited qualities, present in the fertilised ovum, the evolution of which is controlled by (2) internal influences—internal secretions (including the effects of 'sex'), the mutual influence of the muscles upon one another, and of the fibres upon one another, and the internal variations amongst the fibres; and by (3) external circumstances—work, food, habit, and, indeed, the ordinary and extraordinary conditions of extra-uterine life. Up to the time of birth, in at any rate the higher mammals, perhaps in all the Eutheria, hyperplasia characterises the growth of muscle; while after or about birth, hyperplasia ceases, and extra-uterine life brings about a selection of some of the fibres at the expense of their neighbours. In other words, during extra-uterine life, muscle, according to its position, suffers more or less a reduction in the number of its fibres, the degree of which is expressive of its functional importance. The surviving elements are at the same time greatly hypertrophied, and the extent to which this takes place is also expressive of the work which the muscle performs, or of which it is capable.

Note.—Since the above was written, I have determined by calculation the number of fibres, &c., in the biceps of the mother of the first three stages recorded on p. 599. The following should be added to the table given:—age, 3 years 5 months; female; fibres, 32,039; p. square of $\cdot 0263$ mm., $0\cdot 54$; area of section, $41\cdot 5$; area of fibre, $0\cdot 0015$; percentage of fibres, 38. This shows that the last stage given in the table is much more than 3 years old.

ON A MODIFICATION OF THE RUTHERFORD MICRO-
TOME. By DAVID FRASER HARRIS, M.D., C.M., B.Sc.
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Andrews.*

PRACTICAL histology still owes its debt of gratitude to the introduction by the late Professor Rutherford, about 1867, of a microtome,¹ by which, at small cost and with comparative speed, sections of tissues of every description could be cut in numbers sufficiently great to supply large practical classes. Though the paraffin method is the one, *par excellence*, for turning out work of the most delicate character, the method of freezing in gum is still the most suitable for any sections which are purposely cut thick—such as injected organs—as well as for all extra large sections, such as the pyloro-duodenal junction, ciliary region of a large eye, large section of kidney, cerebral cortex, the scalp, transverse section of entire spinal cord, a large epiglottis, a large Gasserian ganglion, transverse section of an œsophagus, a large tongue; and it is the only available method for tissues of exceptional density or resistance, such as bone, tooth-in-jaw, the l. s. and t. s. tendon, the optic pore of a large tough eye, t. s. and l. s. nail, etc. Several ‘Golgi’ preparations of the central nervous system are cut on the small freezing microtome.

Three years ago (February 1896), when Demonstrator of Physiology under Professor M’Kendrick, I devised a microtome based structurally upon the Rutherford instrument, but modified in the following particulars:—

1. The cubic capacity of the chamber for the freezing mixture has been considerably increased, thus permitting an absolutely larger quantity of ice and salt to be used, and so ensuring the tissue in its block of gum (saturated aqueous dextrine) remain-

¹ This instrument was first described by him in this *Journal*, May 1871, in a paper “On some Improvements in the mode of making Sections of Tissues for Microscopic Observation.”

ing solid for a relatively long time,—a convenient thing if one is liable to be interrupted while cutting.

2. The gum-well has been placed *centrally* in the elliptical ice-box: this permits of the freezing-mixture being more thoroughly packed in on all sides of the well; the tightness of the packing is further greatly aided by the pressure of a downwardly directed metal rim or flange on the edge of the ice-box.

3. Less of the well projects above the surface of the ice-box; this obviously helps to keep the gum longer frozen.

4. The upper surface of the platform, which raises the frozen tissue, is of brass, deeply corrugated, and this, along with a transverse, wedge-shaped bar of metal, around which the gum freezes in a dovetailed fashion, effectually prevents the block ever becoming loose, as it sometimes does when very dry (*i.e.*, very cold), on a perfectly smooth platform, or from even tilting to one side, as not unfrequently happens when the platform is high up towards the end of cutting.

5. For the circular plate of glass surrounding the well, a pair of glass covered rails has been substituted.

In the older form, the knife passed over glass, tissue, glass, and in a few strokes the edge was injured; in the present form, as in the Cathcart microtome, the cutting portion of the knife-edge never passes over anything but tissue.

The glass rails (*a*) must not be screwed to the brass rails, but cemented on, and should be dovetailed under brass flanges at the end of the rails. If merely screwed to the metal rails, the glass rails are not only very liable to be broken through weakness where they are bored, but by mere screws they can never be held down so as to be perfectly steady; they can still oscillate sufficiently to yield a wavy section.

Further, (*b*) the upper surface of the rails should be convex, and not flat, so that the knife touching the convexity touches them along a line instead of a surface, and thus (1) friction is reduced, and (2) the amount of knife-edge injured is diminished.

There is (*c*) another advantage in convex rails: the instant the knife is felt to touch both rails, we know that it is perfectly level; but the moment we feel the knife touch both rails which have flat surfaces of some width, we cannot be sure that the knife is in a horizontal plane: it may quite easily be felt to

touch both rails, and yet be in contact with more of one rail than the other. The extra pressure usually given by the right hand accounts for this. All parts of the microtome should be very stout, especially the rails, so as to permit of no dipping of them at their centres opposite the well.

The well must on no account be cast in the same mould as the rails; that is, some movement on the part of the well must be allowed for, independently of the rails. Occasionally there is a slight tendency on the part of the well to move upward (from the block freezing to its sides): if this is accompanied by a movement of the rails at their middle (for they are fixed at the ends), the glass will certainly be cracked. It greatly adds to the comfort of the operator if the milled head by which the screw is turned is as large as possible: the fingers are not cramped in turning it; and if the resistance to be overcome is considerable, one has so much more power with a large than a small wheel.

There is nothing better than pure vaseline with which to smear the interior of the well, so as to prevent the block freezing to the metal; oil has disadvantages too obvious to mention.

ON PROTEID DIGESTION IN AMMOCCETES.¹ By
R. ALCOCK, Bathurst Student of Newnham College, Cambridge.

IN all the higher vertebrates digestion is carried on by means of the secretion of specialised glands, localised in certain definite portions of the alimentary canal, or of glandular masses which are formed as appendages of the same. The formation of a peptic ferment is confined to the glands of the stomach, of a tryptic ferment to the pancreas, and of diastatic ferments to the salivary glands and pancreas. Passing to lower vertebrates, we find in Amphibia that glands secreting a peptic ferment are not restricted to the stomach, but extend oralwards into the œsophagus, which, in the frog, Swiecicki (33) has shown to be more active in digestion than the stomach. In fishes, the most various modifications are found in the size of the stomach, and in the absence or presence of the various glands and their position. Stannius (34) states that a stomach is absent in *Scomberesoces*, the Labridæ, Cyprinidæ, Cyprodontidæ, Loricaria, and Symbranchidæ. Amongst the Cyprinidæ, Edinger (35) states that in *Cobitis fossilis*, *Tinca vulgaris*, and *Abramis barbio* there is no histological evidence of any glands in the stomach, a fact which is confirmed in the case of *Tinca vulgaris* by the chemical experiments of Krukenberg (36), who finds no trace of peptic ferment in the fore-gut. These variations occur in very closely allied fishes: according to Rathke (37), *Gobius melanostomus* has no stomach, whilst that of *Gobius batrachecephalus* is relatively large. The appendices pyloricæ are altogether absent in many families, including those mentioned above as being without stomach, and when present the number varies to an extraordinary extent, ranging from 1 to 200 in different families. A pancreas is present in all Elasmobranchs, and absent in many Teleosteans.

¹ An abstract of this paper was published in the *Proceedings of the Cambridge Philosophical Society* in 1891, vol. vii. p. 251. The paper itself was written in 1892, but has not been published until now.

Krukenberg (36) shows that the position of both pepsin- and trypsin-forming glands in fishes is subject to great variation: the peptic region in *Scyllium*, *Mustelus*, the Rays, and *Trygon*, and among the Teleosteans in *Cyprinus carpio*, *Anguilla vulgaris*, *Esox lucius*, etc., is not limited to the stomach, but extends for some way down the intestine, and in some Teleosteans the pancreatic region extends forwards into the stomach. Pepsin-forming cells are altogether absent in many Cyprinoidæ and some Gobiidæ, whilst, on the other hand, a pancreatic gland is absent in many Physostomi. His researches show that in fishes very various organs, *i.e.*, the mucous membrane of the stomach and intestine, the appendices pyloricæ, the pancreas, and the liver, can yield a tryptic secretion without the presence of one organ excluding the others. In many Physostomi the liver includes cells which have a pancreatic function, the secretion entering the alimentary canal by means of the bile-duct; in *Barbus fluviatilis* the gall-bladder itself containing the ferment, whilst in Carps the two secretions mix after the bile has left the gall-bladder. He also finds a diastatic ferment in this hepatopancreas, as he names this combined liver and pancreas, but in no case does he mention finding a peptic ferment. Krukenberg's (36) researches on the pancreas of young Selachians show that whilst a plentiful pepsin production is found in the fore-gut, the pancreas only begins to function at a later age, and is then very active in digestion. In young Rajidæ and Squatina which he vivisected he found no trypsin present, and in a living embryo of *Acanthus vulgaris*, where the yolk sac was still large, the secretion of the stomach was richly peptic. He thinks that in Selachians, and possibly other fishes, the peptic digestion predominates in youth, the tryptic digestion developing later; and he suggests, for this and other reasons, that in primitive vertebrates the proteid digestion was rather peptic than tryptic. Whether these variations from the ordinary type are due to retrogressive changes, or whether they indicate a primitive condition, the general conclusion drawn from these comparisons is, that in fishes the digestive secretion is much more diffused than in higher vertebrates, both the position and nature of the glands being subject to modification, and that, therefore, the evolution of the digestive organs is in the

direction of a greater concentration and specialisation, from a more diffused and less differentiated condition. If the above conclusion is justifiable, it should be borne out by a study of the digestive processes in the most primitive of fishes, the Cyclostomes. With the exception of one unsuccessful experiment of Krukenberg's (36) on *Petromyzon fluviatilis*, I have been unable to find that any physiological observations have been made on the digestion of any Cyclostome; so, at Dr Gaskell's request, I undertook the following experiments, with the object of showing the nature and position of the digestive ferments in *Ammocetes*.

ALIMENTARY TRACT.

The alimentary tract of *Ammocetes* consists of (1st) the branchial region or pharynx, (2nd) the narrow tube or fore-gut, called by Rathke (37) the œsophagus, and by Langerhans (21) and Schneider (11) the stomach; it leads from the branchial region to the mid-gut, and terminates posteriorly at the entrance of the bile-duct where the sudden enlargement of the alimentary canal marks the beginning of the 3rd region, the mid-gut or intestine proper. The glandular appendages in connection with these parts are the thyroid gland, opening on the floor of the branchial cavity, in the ventral middle line between the 3rd and 4th branchial cleft, and the liver, with its duct opening into the intestine.

In the branchial region the epithelium lining the branchial folds, consistent with its function of allowing an interchange of gases, is a single layer of flattened cells covering the capillaries. The part of the branchiæ free from folds, and the wall of the branchial chamber facing it, forming a chamber, opening externally by the small branchial openings, described by Nestler (16) as the Vorkammer, is lined by an epithelium consisting of three different kinds of cells. There are several layers of ordinary epithelium cells, the lower ones rounded with large nuclei and the upper cells more flattened. Very conspicuous among these small cells are the large glandular cells, described by Nestler (16), arranged in groups of five or six together, and corresponding in height to the whole thickness of the epi-

thelium: they are swollen at the base and smaller at the tip, and the nuclei are flattened, and pressed against the bases of the cells. The top layer of cells in this region is thin and plate-like, and is so arranged as to leave a small gap above the centre of each group of glandular cells, where the tips converge together at the surface.

The epithelium lining the branchial cavity, into which the branchial pouches open internally, is for the most part two-layered ordinary epithelium, the most superficial cells having a thin cuticular border, the exception to this being along the lines forming the system of ciliated cells described by Schneider (11), where there is only a single layer of columnar cells, with a thick cuticular border and strongly ciliated. The dorsal ridge and the two ventral ridges bearing these ciliated cells converge together posteriorly and dorsally at the opening of the narrow anterior intestine into the branchial region, and the lining of this tube consists of similar columnar cells, with a very distinct cuticular border, and uniformly ciliated. The end of this region is marked by the entrance of the bile-duct and the simultaneous enlargement of the lumen of the alimentary canal. The rest of the intestine is a straight tube, gradually diminishing in volume to the anus, the characteristic horseshoe shape of the lumen being due to the large longitudinal ridge or spiral valve projecting into it, the whole of the ridge as well as the walls of the intestine being highly vascular. The cells forming the epithelial lining of this region are uniform in character, being tall columnar cells, with a distinct cuticular border, but becoming slightly lower and broader as the intestine diminishes in size. In the anterior dilated portion of the intestine there are some slight prominences, forming small longitudinal ridges, consisting of ciliated cells, but the rest of the intestine is unciliated. There is no histological evidence here of the presence of secreting cells, the whole structure of this region suggesting an organ of absorption rather than of digestion. On the other hand, the groups of large cells in the branchial pouches are evidently of a glandular nature: their contents are usually clear and slightly stained, but sometimes near the free ends can be seen a collection of deeply stained granules; more frequently a stringy mucous secretion is seen issuing from them. These cells are

abundant over the whole surface of the Vorkammer, but in the most anterior branchial pouch it is very striking to find that most of the branchial folds themselves on the anterior wall are covered by an epithelium of the same character, and apparently are no longer respiratory in function (*cf.* fig. 15 in Gaskell's paper, p. 664). A large amount of mucous secretion is thus poured into the branchial region, and I am convinced that under normal circumstances the cells above described are the source of this secretion; but, on the other hand, under some conditions, as by artificial stimulation with chloroform vapour, the superficial cells of all parts are apt to burst up, cells and remnants of cells, surrounded by a mucous substance, being seen everywhere. Nestler seems doubtful whether the normal mucous secretion is not due to such a process.

THYROID.

The thyroid of *Ammocetes* has been described most accurately by Schneider and Dohrn, and it is unnecessary for me to enter into a detailed description of the organ.

Schneider (11) described the appearance of granules in the long-pointed cells of the thyroid as resembling the border region in the cells of the mammalian salivary gland. He finds in the gland a trace of neutrally reacting fluid; the secretion, he says, is finely granular, and collects in the longitudinal slits into which the gland cells open.

Dohrn (27) also is of the opinion that the thyroid is an organ for secretion, especially for mucous secretion, and suggests that it would be of interest to prove whether the secretion has any digestive function. In my specimens the canals of the thyroid are always singularly free from any secretion whatever; and though the cells have sometimes a dotted appearance when seen in section, to my mind neither their shape nor their general appearance or that of the nucleus in any way suggests a secretory function. The isolated cells after maceration are seen to be long and attenuated, ending in a pointed hair-like portion which projects *in situ* into the lumen of the canal. The nucleus lies in the enlarged base of the cell

and is very round and distinct. I can see no evidence in such isolated cells, or in section of a granular as opposed to a non-granular portion of the cell, and am inclined to think such an appearance in section is due to the arrangement of the thin portions of the cells. The cells are often of a wavy and undecided outline, and do not form a series of straight converging lines in section, but cross and recross each other, and frequently leave gaps between, all of which conditions help to give a dotted appearance.

LIVER.

The only glandular organ in connection with the intestine is the liver, with its large gall-bladder. In structure it is a typically tubular liver throughout, as shown by Langerhans (21), Schneider (11), and Shore (32), and I can see no evidence of any differentiation of function in the cells. In conjunction with the liver, I ought to mention a small collection of glandular follicles embedded in the wall of the gut, just opposite the entrance of the bile-duct. These follicles are commonly considered to be the rudimentary pancreas by Langerhans, Bojanus, Rathke, and A. Müller, but Schneider is inclined to consider them as the spleen. There is no duct by means of which the secretion formed could be poured into the intestine; some of the follicles seem to have no communication with the intestine, while others can be seen to have an opening close against the base of the epithelium cells. As I have not been able to discover the existence of any pancreatic ferment, I see no reason for dignifying these few small follicles by this name.

On transformation, the liver becomes completely separated from the alimentary canal, the duct becomes obliterated, and the liver itself undergoes fatty degeneration. At the same time the small glands in the walls of the intestine, which have been called pancreas, form quite a prominent ring, so as to suggest that if these glands are not functional in the larval condition, yet they may become so on transformation. I have not had sufficient material to satisfy myself on this point.

CHEMICAL EXPERIMENTS.

In order to test for the presence of digestive ferments, I made extracts of the different tissues in glycerine, or in .2 per cent. hydrochloric acid solution, and in 1 per cent. sodium carbonate solution. I used carmine-stained fibrin, after Grützner's method, and always used control experiments with fibrin, to which .2 per cent. HCl alone was added, and frequently also control experiments, with an extract in .2 per cent. HCl of some tissue of the animal, which is inactive in digestion.

As already mentioned, Krukenberg failed to get any evidence of digestion in the one experiment he made. I also have occasionally failed to get any evidence of digestion, even in the extracts of those organs or tissues which undoubtedly contain a digestive ferment, and the analysis of the large number of experiments which I have made has led me to the following conclusions, which I give here partly as a guidance to others who may desire to repeat my experiments, partly because they are characteristic of the behaviour of peptic ferment in higher animals, and therefore go to prove that I am justified in speaking of the ferment present in *Ammocetes* as pepsin.

1. In the first place, it is very advantageous to experiment on animals freshly caught and in good condition. When a fresh batch of *Ammocetes* arrived, I never failed in getting good results, but in the case of some *Petromyzon fluviatilis* which had been kept in the laboratory for some days, and with *Ammocetes* which had been kept for months in the laboratory, the evidence of digestion sometimes failed altogether, and the extracts were always much less active than those obtained from fresh specimens.

2. It is very advisable to dissect out the different tissues in air, and not under water, as I have always found the extracts inefficient after the tissues of the dead animal have been in water.

3. The digestion is much more rapid when the extracts are kept at a temperature of 38°-40° C. than at a temperature of 15°-20° C., which agrees with Krukenberg's experiments on the digestive ferments of fishes, and also on those of invertebrates.

4. No glycerine extracts are active unless the tissue be well pounded up with sand at the time of preparation, and under these circumstances the glycerine extract is as powerful as the .2 per cent. HCl extract, and has an advantage over the latter in that it can be kept for any length of time, whilst the .2 per cent. HCl extract after a time loses its efficiency, probably owing to putrefactive processes.

5. The ferment is extracted much more rapidly at a temperature of 38°–40° C. than of 15–20° C.

6. The ferment is extracted much more rapidly by .2 per cent. HCl than by glycerine.

I have also made extracts with glycerine, and also with water slightly acidulated with acetic acid, and added to them a solution of 1 per cent. Na_2CO_3 and fibrin unstained, but I have never succeeded in finding any evidence whatever of a tryptic ferment in any of the tissues. Nor have I found any trace of a diastatic ferment.

The object of my experiments being in the first instance to find out which parts of the alimentary canal were mainly concerned in proteid digestion, I divided the alimentary tract into four portions and made extracts of each. These portions were (1) the lining of the pharyngeal cavity; (2) the thyroid gland; (3) the liver; (4) the intestine, inclusive of the narrow anterior intestine, the so-called stomach. The extracts were made not from a single *Ammocetes* but from a number of them, varying from 2–6 or more; the individuals were as large as I could obtain, so that the total amount of tissue extracted in each experiment was considerable, except of course in the case of the thyroid gland, which is a comparatively small organ. In this case I made special experiments with extracts made from a larger number of glands, without, however, any difference in the result.

The number of separate experiments I have made is very large, and the results are exceedingly constant. They show most clearly that the formation of pepsin occurs to a greater or less extent over the whole alimentary tract, but that the walls of the pharyngeal cavity are of greater importance as an organ for digestion than the intestine. The extract of the intestine always shows some signs of proteolytic activity; but when

the intestine has been thoroughly cleaned of mud, and consequently of the ferment poured into it from the liver, the activity of the extract is far inferior to that of the liver, pharynx, or skin.

I give the details of three experiments to illustrate the difference of activity of the different organs referred to.

June 25, 1891.—Two *Ammocoetes* used. Tissues dissected out in air, and .2 per cent. HCl extracts made; the digestion carried on at a temperature of 40° C., equal amounts of coloured fibrin being added to each extract at 12 o'clock. Intestine not brushed out.

Time.	Pharynx.	Intestine.	Liver.	Skin.	Thyroid.	Muscle.	.2 % HCL
12.5	..	..	faint pink.				
12.10	faint pink.	..	distinct pink; fibrin breaking up.				
12.15	pink; fibrin breaking up.	..	deep pink.				
12.20	distinct pink.	faint pink.	deeper pink.				
12.25	deeper pink.	slightly pinker.	deeper pink; most fibrin digested.				
12.30	"	"	deeper pink.	faint pink.			
12.35	most fibrin digested.	distinct pink; fibrin breaking up.	"	"			
12.40	deeper pink.	deeper pink.	all fibrin digested.	slightly pinker.			
12.45	all fibrin digested.	"	..	distinct pink; fibrin breaking up.			
12.50	..	"	..	deeper pink.			
12.55	..	"	..	"			
1	..	"	..	"			
1.15	..	most fibrin digested.	..	deeper pink; most fibrin digested.			
3	all fibrin digested.	all fibrin digested.	all fibrin digested.	all fibrin digested.	no change.	no change.	no change.

We see that the fibrin was entirely digested by the liver extract in 40 minutes, by the pharynx in 45 minutes, while in the case of the intestine and skin it was not entirely digested in 75 minutes.

June 26, 1891.—Corresponding experiment to that of June

25. Two Ammocetes used; digestion at temperature of 40° C.; equal amounts of coloured fibrin, but intestine of both Ammocetes cut open, and the mud carefully cleaned out with a dry brush before making the extract.

Time.	Pharynx.	Intestine.	Liver.	Skin.	Thyroid.	Muscle.	.2% HCl.
11.45							
11.50	..	..	faintest pink.				
11.55	..	..	faint pink.				
12	faint pink.	..	distinct pink; fibrin breaking up.	faint pink.			
12.5	"	..	deeper pink.	"			
12.10	"	..	"	distinct pink; fibrin breaking up.			
12.15	distinct pink; fibrin breaking up.	..	most fibrin digested.	pinker.			
12.20	pinker.	..	deeper pink.	"			
12.25	"	..	"	"			
12.30	"	..	"	"			
12.35	"	..	all fibrin digested.	most fibrin digested.			
12.40	"	..	"	"			
12.45	most fibrin digested.	..	"	"			
12.50	"	..	..	"	
12.55	"	..	..	all fibrin digested.			
1	"	faint pink.	..	"			
1.15	nearly all fibrin digested.	"					
4	all fibrin digested.	still faint pink; fibrin little changed.	all fibrin digested.	all fibrin digested.	no change.	faint pink.	no change.

This experiment, compared with the previous one, shows again that the liver is most active, and that the pharynx is much more active than the intestine when the contents of the intestine are carefully removed.

July 14, 1891.—The following experiment, like the preceding, was made with .2 per cent. HCl extracts at temperature 40° C. But four Ammocetes were used, two having been used in the preceding experiment; the extracts were therefore approximately twice as active. In this instance the contents of the intestine were brushed out.

Time.	Pharynx.	Intestine.	Liver.	Skin.	Thy- roid.	Muscle.	Brain, etc.	.2 % HCl.
11.55 11.57	..	..	distinct pink; fibrin breaking up.					
12	faint pink.	faintest pink.	deeper pink.	faintest pink.				
12.5	distinct pink.	faint pink.	most fibrin digested.					
12.10	deeper pink; most fibrin gone.	fibrin breaking up.	"	fibrin breaking up.				
12.15	"	deeper pink.	all fibrin digested.	pinker.				
12.20 12.25	all fibrin digested except fragments.	most fibrin digested.	..	all fibrin digested but fragments.				
12.45	all digested.	all digested.	all digested.	all digested.	no change.	faintest pink.	no change.	no change.

The above experiments are not quantitative, but I took approximately equal amounts of the tissues, and the results were on the whole uniform, and I think fairly show that a peptic ferment exists in some of the tissues, and that, as far as the alimentary canal is concerned, the liver is the most active organ, then comes the pharynx, and lastly the intestine.

As far as they go, then, my experiments bear out Krukenberg's theory as to the digestion in primitive vertebrates being peptic rather than tryptic, and also the theory that the production of the ferment is more diffused than in the higher vertebrates; and they further show that the most anterior portion of the alimentary tract—the pharyngeal cavity—is more important in digestion than the posterior part—the intestine. Recalling the description of the glandular-looking cells in the pharyngeal region which are so numerous and so conspicuous, especially in the first branchial pouch, it suggests itself that they may be the cells which secrete the ferment.

It is absolutely certain that the activity of the pharyngeal region is not due to a secretion from the thyroid gland, for I have never succeeded in obtaining any sign of digestion in the tube containing the thyroid extract. In every case the contents of the control tube, containing only .2 per cent. HCl and fibrin, were absolutely unaltered, and in every case the presence of the thyroid gland made no difference. It is not simply a question of amount of material, for I have carefully extracted all the

thyroid glands of four to six large *Ammocetes*, and that extract was as ineffective as that of a single gland. It is, then, perfectly certain that the thyroid does not take part in the digestion of proteids. It is, to my mind, equally certain that Dohrn's suggestion that the thyroid is a mucous gland is entirely wrong. In the first place, as already mentioned, there is never a sign of mucous secretion in any of my sections of the thyroid, and its cells are totally different in histological structure from cells of mucous glands; in the second place, it does not stain with the characteristic purple colour when stained with thionin, as is the case with all mucous-secreting tissues in *Ammocetes*, just as in other animals. My experiments, then, give no evidence whatever for the view that the thyroid takes any share in digestion, but, on the contrary, give very decided evidence against such a view.

THE SKIN.

Seeing that the lining epithelial cells of the pharyngeal cavity possess digestive properties, it seemed possible that the peptic ferment might be still more diffused in the tissues of the *Ammocetes*, and I therefore proceeded to test a number of its tissues in the same manner as I had already done for the alimentary canal; and for that purpose I have made extracts of the muscle, skin, kidneys, generative organs, central nervous system, and blood, and in no case has the extract of generative organs, of nerve-tissue, or of blood shown any sign of activity. In the case of extract of both the muscle and kidney substance, a slight tinge of colour has occasionally appeared in the solution after long waiting, but in no case have I seen anything in the smallest degree comparable to the activity of the pharynx or skin extracts.

The most startling fact brought to light by this series of experiments is undoubtedly that the cells constituting the external epithelium of the body produce a peptic ferment capable of digesting proteid in a .2 per cent. HCl solution. It is seen from my experiments, examples of which have already been given on pp. 620-622, that this digestive activity of the skin is not a slight and doubtful one, but, on the contrary, is comparable in definiteness and rapidity with that of the liver itself. Thus, in the three experiments quoted, most of the fibrin

was digested by the skin extract in 75 minutes, 55 minutes, and 30 minutes respectively, while in the same experiments the liver extract digested most of the fibrin in 25 minutes, 30 minutes, and 10 minutes respectively.

This digestive activity of the skin is due to the secretion of the epidermal cells; for, by means of stimulation by the vapour of chloroform, it is possible to obtain a considerable secretion from the epidermal surface, and the extract of this secretion with .2 HCl solution digests fibrin in the most evident manner. I append the protocol of an experiment of this kind.

July 14, 1891.—One large lamprey, killed with chloroform. Chloroform caused considerable secretion of the skin. Secretion was scraped off and put in .2 per cent. HCl. Experimental temperature 38° C.

July 16.—12.15, fibrin added. 12.30, very faintest possible tinge of pink. 12.45, decided tinge of pink. 1.30, pink; a good deal of fibrin gone.

July 17th.—10 A.M., all the fibrin gone.

Such a phenomenon as the secretion by the epidermis of a peptic ferment being, to my knowledge, unprecedented, I made a few experiments on the skin of various animals, viz., the frog, skate, eel, crayfish, snail, and earthworm, and found the extracts quite inoperative, except that of the crayfish skin. In this case the extract was made of the epithelium lining the internal surface of the carapace, and the results of four experiments were as follows:—

April 27, 1892.—Three crayfish used, killed by chloroform. Fibrin put into extract of lining tissue of carapace in .2 per cent. HCl solution, at 40° C., at 12.30. At 4 P.M. fibrin broken up. Next morning fibrin all in fragments, still a good deal left undigested.

May 6, 1892.—One crayfish, killed by nicotine. Fibrin put into extract of lining tissue of carapace in .2 per cent. HCl solution, at 40° C., at 5 P.M. Next morning all the fibrin completely digested.

In the next experiment I made careful extracts of a large number of different tissues of the crayfish, treated them all in precisely the same manner, and noted the contents of the test-tubes for 1½ hours. The result is given in the following table, May 10th, 1892.

TWO CRAYFISH.—Tested. Blood very alkaline. Muscle alkaline. Liver slightly alkaline.

Tuesday, May 10. 3.55	Liver, 2 p.c. HCl.	Liver slightly acid, ext. 1 p.c. Na ₂ CO ₃ .	Skin.	Intestine.	Stomach.	Green Glands.	Generative Organs.	Blood.	Muscle.	Gills.
4										
4.10	tinge pink; fibrin break- ing up.	..	..	..	?	very slight tinge pink; fibrin break- ing up. distinct pink.				
4.20	distinct pink; fibrin broken up.	..	..	..	v. faint pink.	deep pink; fibrin in fragments.				
4.30	pink; fibrin in fragments.	..	fibrin begins to break up; colour ob- scured by colour of solution.	?	v. faint.					
4.45	pink; fibrin mostly gone, looks granu- lar.	..	fibrin more broken up.	faint pink.	pink; fibrin breaking up.	deeper; fib- rin mostly gone.				
5	more gone.	..	fibrin frag- ments.	pink; break- ing up.	pinker; fibrin in frag- ments.	deeper; near- ly all gone.	..	..	..	v. faint pink; begins to break up. faint pink.
5.15	fibrin more finely granu- lar.	..	does not get on much; too much fibrin in.	deep pink; good deal gone.	deep pink; mostly gone.	very deep pink.	..	faint pink; f. begins break up.	..	
5.30	add 2 p.c. HCl; all fibrin dis- solves.	..	do.	pinker; fibrin in frag- ments.	practically all gone.	almost all gone.	..	pink; break- ing up.	..	breaking up; still faint pink.
Wednesday.	all gone.	..	good deal gone.	good deal gone.	all gone.	all gone.	no change.	good deal gone.	no change.	not quite all gone.
Thursday.	..	all gone.								

This experiment demonstrates clearly, as is seen indeed throughout my series of experiments, that some tissues give no sign of any digestive activity even after 18 to 20 hours' contact with fibrin at a temperature of 40° C. It confirms also an experiment of Krukenberg, that the green glands possess peptic power. In his paper he says that he will give an explanation of this peculiar fact in a later paper, but I have been unable to find any further mention of it in any paper of his that I have been able to obtain. This experiment shows further that the blood of the crayfish possesses some digestive power, and it might therefore be argued that the activity of the lining membrane of the carapace was due to its blood contents, and not to any special secretion from its cells. Against this argument is the fact that the muscle contained as much as, or more blood than the tissue lining the carapace, but yet the muscle extract was quite inoperative; and also, I purposely tried to obtain the epidermal tissues as free from blood as possible.

In another experiment of the same kind I obtained the following results:—

TWO CRAYFISH.—(*Killed with chloroform.*)

<i>Saturday, May 28.</i>	Liver.	Liver 1 p.c. Na ₂ CO ₃ .	Skin.	Blood.	Green Glands.	Muscle.	Eggs.	2 p.c. HCl.
3.20								
3.30								
3.45	fibrin breaking up.	..	fibrin breaking up.					
4								
4.10	..	..	..	v. faint pink.				
4.20	very little signs of digestion in any ;			blood is the pinkest.				
4.30	v. faint pink.	..	..	a little- pinker.	..	no signs of fibrin breaking up.	no.	
5								
<i>Monday, May 30.</i>	faint pink ; most fibrin quite unchang'd	fibrin all in frag- ments.	practically alldigest- ed. only small frag- ments left	some frag- ment left; pinker than liver.	faint pink; most fibrin un- changed.	no.	no.	

In this experiment neither the liver nor the green glands, nor, indeed, any parts of the animals, showed much evidence of

activity; yet still the extract of the lining of the carapace ultimately digested the fibrin. In this case, also, the extracts of the muscles and generative organs were ineffective, although that of the blood was able to effect more than the liver extract itself.

In close connection with these experiments of mine on the digestive power of the lining epithelium of the carapace of *Astacus*, and of the external covering of *Ammocetes*, are Hardy's experiments on the carapace of *Daphnia*.

He describes (24) in *Daphnia* the existence of a slime secreted by the ectoderm cells, and thrown on to the surface, probably through pores in the carapace. This substance gives the brilliant rose colour in artificial light when stained with methylene blue, and granules in the cell-substance of the ectoderm cells show the same rose colour, whilst the rest of the cells remain blue. A similar rose coloration appears, as described in Hardy's paper, in certain granules in the superficial cells of the skin of *Ammocetes* stained in methylene blue. These granules are those nearest the cuticular border, and the pores perforating the cuticular border can be seen filled with the rose-coloured secretion, a film of it also adhering to the surface of the skin.

The explanation Hardy suggests of the function of this slime, in the case of *Daphnia*, is that it acts as a protection against the attacks of parasitic growths, either (1) mechanically, by continually affording a fresh surface, which is constantly dissolved and washed away by the water in which the animal lives, or (2) by means of a specific poison contained in the slime.

In the case of *Ammocetes*, the latter seems to be a possible explanation as to the purpose of a proteolytic ferment formed over the whole surface of the body. The animal lives buried in the mud, and has no mechanical means of keeping itself free from the attacks of parasites, which have every opportunity of establishing themselves upon it. The ease with which parasitic growths can establish themselves on the surface of the lamprey, when deprived of its protecting epithelium, is exemplified by the experiment described by Gaskell in the case of *Petromyzon fluviatilis*, and in connection with this experiment I would mention that extracts of the skin of *Petromyzon fluviatilis* demonstrated the presence of a peptic ferment similar to that

found in the skin of the Ammocetes of *Petromyzon planeri*. Another instance equally instructive was observed by me in the case of certain crayfish, some of which had been kept alive for some days after division of the cesophageal commissures. In these cases the animals were unable to preen themselves, and it was very interesting to see how quickly, under these circumstances, fungus began to grow on the ventral portions of the body, which they are in the habit of keeping clean by preening themselves, while at the same time the carapace, which is out of reach of preening operations, remained as clear of fungus as in the intact animal. These experiments seem to show that the carapace is kept clear from parasites by some other method; and bearing in mind the undoubted fact of a secretion on the surface of the carapace of *Daphnia*, it seems probable that a similar secretion should occur in the carapace of *Astacus*. Indeed it is more than probable, for Mr Hardy has given me permission to state that he has seen distinct drops of secretion appear over the surface of the carapace of the crayfish after it had been carefully dried, when he had injected peptone into the animal.

All the evidence, then, taken together, points to a secretory activity of certain of the epidermal cells of Ammocetes, *Astacus*, and *Daphnia*, for the purpose of keeping the surface free from parasitic growths, and it suggests forcibly that an essential element in this secretion is something in the nature of a peptic ferment.

I have attempted to find out which elements of the skin of Ammocetes secrete this digestive ferment, and think it worth while to give the result of my experiments, although I do not consider that they give anything more than a strong probability as to the kind of cell especially concerned.

So much has been written on the subject of the skin of *Petromyzon planeri*, *Petromyzon fluviatilis*, and Ammocetes, and the various authors have come to such contradictory conclusions as to the functions of the constituent cells, that it seems advisable to recapitulate their statements.

The skin consists of an epithelium resting on the peculiar laminated layer, below which is a layer of loose fatty tissue. In the epithelium, several different kinds of cells are to be dis-

tinguished. The ordinary epithelium cells are small, with large round nuclei, and are several layers deep. These cells are very variable in shape, the deepest being somewhat elongated vertically and small, those above are larger and rounder, whilst the most superficial cells are characterised by a very distinct and perfectly uniform cuticular border. Amongst these cells are to be seen, varying in number in different regions of the body, some very large club-shaped cells, with the narrow base touching the laminated layer, and the large rounded end projecting toward the surface. Down the middle of each of these cells is a central core of granular protoplasm, increasing in amount at the rounded end, and in it are embedded two or sometimes three small round nuclei. These cells have a very characteristic appearance when stained with picro-carmin; the central core remains colourless, the nuclei are stained red, and the rest of the cell bright yellow. Besides the club-shaped cells are numerous round or pear-shaped cells, usually situated somewhat superficial to them, or between their rounded heads. These cells have a nucleus in the centre, and are filled with rather large, highly-refractive granules, which stain brown with osmic acid. It may be noticed that the club-shaped cells and the large granular cells always appear together in about the same numerical proportion, and in those regions free from club-shaped cells the granular cells are also absent.

Kölliker (38) was the first to describe these two peculiar forms of cells, which he calls mucous cells and granular cells, but he describes the mucous or club-shaped cells reversed in position, their narrow neck portion reaching the surface through which he supposes they pour their fluid mucous contents on to the exterior; but as, in a superficial view of the skin, no large openings are to be seen among the uniformly cuticular cells of the surface, he concludes the mucous cells have also a cuticular border. The granular cells he tries to compare to the thread cells of the mucous sacs of *Myxine*, which he says are derived from cells in the epidermis lining the sac, and also that comparable cells exist in the epidermis covering the rest of the body. These cells, according to Kölliker, are secretory in function.

Max Schultze (39) corrected Kölliker's description of these

cells, and rejected the name 'mucous cells,' calling them Kolben, or club-shaped cells. He denied their secretory function; but, on account of a transverse striation in their narrow basal portion, and their appearance when seen in polarised light, he was led to believe these cells were of a muscular nature, and supposed them to be in connection with the cutaneous nerves. He rejects Kölliker's ideas as to the granular cells, but makes no fresh suggestion.

H. Müller (40) confirmed Max Schultze's description of the club cells when seen in polarised light. He showed the formation of the cells in *Petromyzon fluviatilis*, and finds they are not all in contact with the laminated layer,—a fact difficult to reconcile with Max Schultze's hypothesis.

F. E. Schulze (41) describes the skin of *Petromyzon fluviatilis*, eel, and other fishes. In contradiction to Leydig (42), who gives it as his view that the mucous secretion of fishes is formed by all the superficial cells of the skin, and not by definite gland cells (die Epidermis selbst ist der Schleim, he says), Schulze says it is confined to certain goblet cells which open on the surface, but are quite distinct from the ordinary superficial cells. He agrees with M. Schultze as to the muscular properties of the club cells, and thinks the granular unstaining core is a secretion; he describes some of the cells reaching very near the surface, and the secretion increasing in amount at the free end of the cell, and he supposes it to be ejected by the force of the muscular contractions of the cell. He describes the granular cells in great detail, and discovers that their long processes unite in an extraordinary dome-shaped structure in the centre of the cell; he supposes the processes to be in connection with the nerves of the skin, and that these cells are therefore nervous in function.

Langerhans (21) never found the club cells reaching the surface in *Petromyzon planeri*, and cannot therefore understand how they can be secretory in function, as F. E. Schulze considers to be the case. He denies the existence of mucous secreting goblet cells, differing from the rest of the superficial cells, as he never found in *Petromyzon planeri* or in *Ammocetes* that the cuticular border of the superficial cells was interrupted by the orifices of such goblet cells opening on the surface.

Langerhans (21) also describes some minute round cells lodged between the other cells of the epidermis, which he compares to the chromatophores of the larval salamander. He discovers cells in the papillæ of the mouth principally, but also all over the skin small cells with a prolongation at each end, that towards the surface having a number of stiff cilia, and these he considers to be nerve endings.

Foettinger (43) divides the cells of the skin of *Petromyzon fluviatilis* into four categories:—1, ordinary epidermis cells; 2, goblet cells; 3, club cells; 4, granular cells; and points out the advantage of staining with picro-carmin, the different cells taking the stain each in a characteristic way. He describes minutely the cells in the different layers of the epidermis, pointing out that in *Ammocetes* and *Petromyzon planeri* the cells are smaller than in *Petromyzon fluviatilis*, but have the same characters; the superficial cells, however, are relatively thicker, and their cuticular border, with its fine pores, much more marked in *planeri* than in *fluviatilis*. Foettinger confirms F. E. Schulze as to the presence of goblet cells in the skin of *Petromyzon fluviatilis* in all regions except the cornea, where the club cells and granular cells are also absent. In *Petromyzon planeri* the goblet cells are smaller, but also distinctly present. The club cells he describes in various stages of development. He only finds the transverse striation in the neck of these cells when treated with Müller's fluid, so he thinks it cannot be compared to the striation of muscle fibres, but, on the other hand, he considers their longitudinal and concentric striation as an indication of a lamellar construction. He says the club cells in *Petromyzon fluviatilis* are not always in contact with the laminated layer: at a certain stage the base is withdrawn from it, the cell alters in shape, and works its way to the surface, finally pushing apart the superficial cells and extruding itself; before this occurs the nucleus has disappeared. He rejects M. Schultze's hypothesis of their muscular nature, and F. E. Schulze's theory that they are organs of secretion, capable of ejecting a fluid elaborated in their interior, but he considers them to be glandular in nature,—the entire cell, or at least that part coloured yellow by picro-carmin, being eliminated. The granular cells he describes, with their fine processes passing in

various directions among the surrounding cells, but denies the existence of the dome-shaped organ in which F. E. Schulze asserts that they unite. He gives no opinion as to their function, but remarks that K  lliker's hypothesis as to their glandular nature was based on the incorrect idea that the processes were directed to the exterior, and F. E. Schulze's theory as to their nervous function is improbable on account of the number of the processes and the general character of the cells. Foettinger (43) describes cells similar to those found by Lov  n and Schwalbe in the tongue of the calf and other mammals; they are cells with two prolongations, one peripheral, one central, the body of the cell small, and almost filled by the nucleus. In *Petromyzon* these are not in special places as in higher animals, but all over the body, but Foettinger does not show their connection with the cutaneous nerves.

Pogojeff (44), struck with the resemblance of the club cells to the endings of sensory nerves in higher animals, compares them to Pacinian bodies, corpuscles of Grandry, and corpuscles of Herbst. Treated with gold chloride, he finds the central core stains purple, while the rest of the cell remains unstained. The central core, according to him, is comparable to the axis-cylinder of a nerve fibre, the two nuclei are little cells, being the true nerve endings, whilst the rest of the cell, arranged round the core in concentric lamell  e, he compares to the connective-tissue lamell  e or tunics enveloping the nervous core of a Pacinian body.

Blomfield (45) describes some irregular oblong cells in the skin of *Myxine*, which stain yellow with picro-carmin, and have no obvious nucleus, but a small red spot which may be the remains of one. He says that these cells, like the club cells of *Petromyzon*, according to Foettinger, grow towards the surface, and are there discharged, and are probably homologous with them. He considers that these cells are of the same nature as the thread cells in the lateral glands of *Myxine*, which also stain yellow with picro-carmin. A second kind of cell in *Myxine* skin he compares to the granular cells of *Petromyzon*; and from their resemblance to certain cells in the lateral glands of *Myxine*, he considers it probable that they contribute some part of the mucous secretion, possibly the more liquid portion.

Finally, Reid (46) has compared the structure of the skin of the eel, of *Myxine*, and of *Petromyzon fluviatilis*, and comes to the conclusion that the club cells of *Petromyzon* discharge slime threads similar to those of *Myxine*.

My chemical experiments having shown that a proteolytic ferment of the nature of pepsin is secreted by the skin, I was anxious to find some indication as to which particular cells produced the ferment. It is noticed by all observers that the club-shaped cells and the granular cells are almost absent on the head, and very few in number in the region of the pharynx, whilst in the tail region they are very numerous and very large, the club cells standing in rows with only small spaces between them, which are filled with the ordinary epithelium cells, and the granular cells are as numerous, being placed above the level of the enlarged ends of the club cells, and alternating with them.

If the club cells or the granular cells took part in the formation of the ferment, the difference in proteolytic activity of the skin taken from the head region and that taken from the tail region should be very marked. Equal amounts of skin taken from the two regions, however, proved to be very similar in proteolytic activity, the extract of the skin from the head region being slightly more active than the other. I had weighed the amounts of skin carefully in one case, and obtained the same result. From this it would appear that it is not the club cells or granular cells which produce the ferment, but rather some cells which are present more uniformly all over the body, presumably the superficial cells. It is to be noticed that in the head region the superficial cells are deeper and more granular than in the tail region, where they are more flattened, indicating a greater secretory activity in the former.

I give in the two following protocols the details of the experiments referred to:—

FIVE AMMOCETES.

<i>March</i> 14th.	.729 gram. Skin head.	.729 gram. Skin body.	.687 gram. Liver.	-2 p.c. HCL
3.41				
3.45	Faintest tinge.	...	?	
3.48	...		Faintest tinge pink.	
3.50	Faint pink, not so deep as liver.	...	Distinct pink.	
3.55	A little deeper; fibrin breaking up.	v. faintest tinge.	Deep pink.	
4	Pink; fibrin frag- ments.	Faint pink; fibrin breaking up.	Deeper; fibrin mostly gone.	
4.5	Deeper.	About two shades less deep than head.	Nearly all gone.	
4.10	Deeper; fibrin more gone.	Fibrin in frag- ments.	Practically all gone.	
4.20	Fibrin mostly gone; not so deep pink as liver.	Deeper; less deep than head.	All gone.	
4.30	Most gone; not quite so deep as liver.	About twice as much fibrin as in head.		
4.40	Nearly all gone; nearly as deep as liver.	A little more gone; still not so deep as head.		
4.50	"	"		
5	All gone.	"		
5.20	...	"		
5.80	...	Almost all gone; very nearly same colour as head.		
5.40	...	All gone but few fragments; same colour as head.	...	No change.

FOUR AMMOCCETES. 40° C. warmed extracts. Approximately the same amounts of skin from head and body regions taken.

Head including skin of pharynx region, body skin from posterior region.

March 9th.	Liver.	Skin head.	Skin body.	.2 p.c. HCl.
4.32				
4.37	v. faint pink.			
4.45	Pink ; fibrin going.	Faintest possible tinge pink.	Faintest possible tinge.	
4.55	Deep pink ; fibrin in fragments.	Pink ; fibrin break- ing up.	Pink ; same as head.	
5.5	Deeper ; fibrin mostly gone.	Deeper pink ; fibrin fragments.	Same as head.	
5.15	Deeper ; nearly all gone.	Deeper.	Same as head.	
5.30	Only few frag- ments left.	Mostly gone ; not so deep as liver.	Same as head.	
5.45	Diluted all the solutions with .2 HCl.			
6	Still fragments left in all.		...	No change.

In both instances the digestion was incomplete, possibly owing to the fact that the fibrin used had been kept many weeks in ether.

The superficial cells appear to be constantly secreting, and after slight stimulation by reagents, such as corrosive sublimate or chloroform vapour, the secretion is increased and the granular contents of these cells disappear, the other cells remaining apparently unaffected. After longer stimulation with chloroform vapour, the granular cells burst up and discharge their contents with such force that the epithelium cells above them are broken off, and after prolonged stimulation the disruption is so violent that practically the whole skin is cast off. The part played by the club cells seems to me somewhat doubtful. I have never seen them being extruded on to the surface in normal, well-pre-

served skin, but after moderate stimulation they seem to elongate, and in some cases appeared to be pushing their way towards the exterior; after more prolonged stimulation they had entirely lost their characteristic shape, and seemed, in fact, to have undergone disruption like the rest of the cells; but I do not feel clear as to whether this is not a mechanical result of the pressure exerted by the bursting of the granular cells.

I think, then, that there is no doubt, from a comparison of the granular cells before and after stimulation, that they are of a glandular nature, and contain probably a more fluid portion of the secretion, whilst the club cells, if they are of a glandular nature at all, supply a more fibrous material.

CONCLUSIONS.

The conclusions I am led to from the above experiments are that—

1. The proteid digestive ferment in *Ammocetes* is of the nature of pepsin rather than trypsin.
2. This ferment is diffuse in position, being found in all parts of the alimentary tract.
3. It is found mainly in the anterior part of the alimentary tract, especially in the respiratory portion of the pharynx and in the liver.
4. The so-called thyroid gland produces no digestive ferment.
5. The skin produces a proteid-digesting ferment similar in every respect to that formed in the alimentary tract.
6. The ferment is formed in the superficial cells of the skin.

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ON THE ORIGIN OF VERTEBRATES, DEDUCED FROM
THE STUDY OF AMMOCCETES. By WALTER H. GASKELL,
M.D., LL.D., F.R.S., *University Lecturer on Physiology ;
Fellow of Trinity Hall, Cambridge.* (PLATE XLV.)

PART IV.—THE THYROID OR OPERCULAR SEGMENT; THE
MEANING OF THE FACIAL NERVE.

IN the last part of this series of papers I ended by briefly stating that the facial nerve supplied a segment which was serially homologous with the branchial segments supplied by the vagus and glosso-pharyngeal nerves, and therefore of the nature of a respiratory appendage, with, however, the striking difference that this appendage was only partly respiratory in function, the anterior part of the appendage being prolonged ventrally, so as to form a ventral tongue, which fits in between the three foremost pairs of branchial appendages, and carries the thyroid gland and pair of ciliated grooves.

I further said that such an arrangement resembled the foremost respiratory appendage or operculum of *Phrynus*, *Thelyphonus*, and in all probability of all the extinct sea-scorpions, *Eurypterus*, *Pterygotus*, etc. In all these forms of scorpions, the operculum, unlike that of *Scorpio* or *Limulus*, carries branchiæ on its posterior half, and in its median and anterior part it carries the terminal genital organs.

I propose in this paper to state fully the nature of the resemblance in the two cases; and in order to make the evidence clear to my readers, I will in the first place give a brief description of the thyroid gland and its history, as shown in the case of *Ammocætes*.

The Thyroid Gland of Ammocætes.

Throughout the vertebrate kingdom it is possible to compare the thyroid gland of one group of animals with that of another without coming across any very marked difference of structure

right down to *Petromyzon*. When, however, we pass from *Petromyzon* to *Ammocetes*, we find that the thyroid has suddenly become an organ of much more complicated structure, covering a much larger space, and bearing no resemblance to the thyroid glands of the higher forms. At transformation the

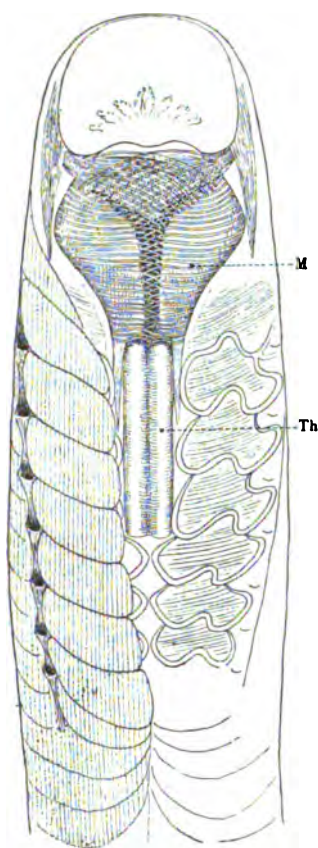


FIG. 1.—Ventral view of head region of *Ammocetes*. Th, thyroid gland ; M, lower lip, with its muscles.

Ammocetes thyroid is destroyed, and the gland in the *Petromyzon* becomes confined to a few follicles resembling those of other fishes, etc. The structure and position of this gland in *Ammocetes* is so well known that it is unnecessary to describe it in detail. For the purpose, however, of making clear my points,

I give in fig. 1 the position and appearance of the thyroid gland (Th) when the skin and underlying laminated layer has been removed by the action of hypochlorite of soda. On the one side the ventral somatic muscles have been removed to show the branchial cartilaginous basketwork. The series of figures on Pl. XLV. represent the nature of the organ upon transverse section at different levels in front of and behind the opening into the respiratory chamber; and in fig. 2 I have sketched the appearance of the whole gland, viewed so as to show its opening into the respiratory chamber, and its posterior curled-up termination.

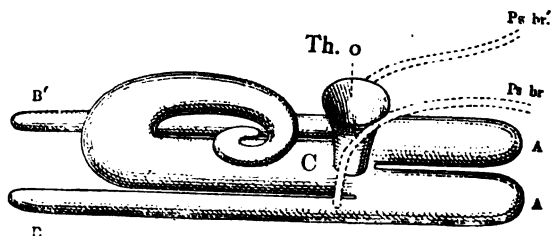


FIG. 2.—Diagrammatic representation of the so-called thyroid gland of *Ammocetes*. C, central chamber; A A', anterior extremity; B B', posterior extremity; Th. o, thyroid opening into respiratory chamber; Ps br, Ps br', ciliated grooves, Dohrn's pseudo-branchial grooves.

The series of transverse sections (1-6, Pl. XLV.) show that we are dealing here with a central glandular chamber C (fig. 6, Pl. XLV.), which opens by the thyroid duct (Th. o) into the pharyngeal chamber, and is curled upon itself in its more posterior part. This central chamber divides, anterior to the thyroid orifice, into two portions A A', giving origin to two tubes B B', which lie close alongside of, and extend further back than, the posterior limit of the curled portion of the central chamber C. The structure of the central chamber C, and therefore of the separate coils, is given in both Schneider's¹ and Dohrn's² pictures, and is represented in fig. 6, Pl. XLV., which shows the peculiar arrangement and character of the glandular cells proper to this organ, and also the nature of the central cavity, with the

¹ A. Schneider, *Beiträge z. Anat. u. Entwickl. d. Wirbelthiere*, Berlin, 1879.

² Dohrn, *Studien zur Urgeschichte des Wirbelthiere Körpers*, viii. "Die Thyroidea bei *Petromyzon*, *Amphioxus* und *Tunicaten*," *Mitth. a. d. Zool. Stat. z. Neapel.*, Bd. vi. p. 49.

arrangement of the ciliated epithelium. The structure of each of the lateral tubes B is different from that of the central chamber, in that only half the central chamber is represented, as is seen by the comparison of the tube B with the tube C in figs. 5, 6, Pl. XLV., so that we may look upon the central chamber C as formed of two tubes similar in structure to the tubes B, which have come together to form a single chamber by the partial absorption of their walls, the remains of the wall being still visible as the septum, which partially divides the chamber C into halves.

Further, sections through the portion A A' show that here as in the central chamber C, four of these glandular lines open into a common chamber, but they are not the same four as in the case of the central chamber, for if we name these glandular lines, as in the figures on Pl. XLV., *a b*, *a' b'*, *c d*, *c' d'*, then the central chamber has opening into it *a b*, *c d*, while the chamber of A and A' have opening into them respectively *a b*, *a' b'*, and *c d*, *c' d'*.

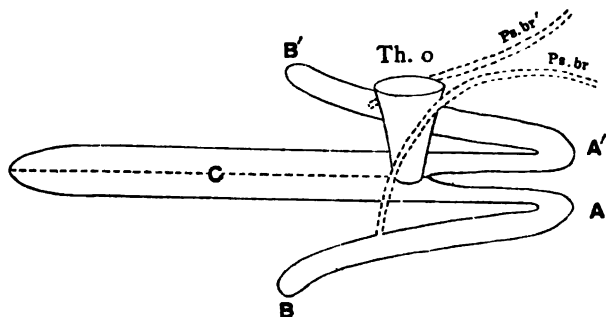


FIG. 3.—Thyroid gland as it would appear if the central chamber was uncurled and the two horns B B' separated from the central chamber.

Further, the sections show that the glands *a* and *b* are continuous with the glands *a'* and *b'* respectively across the apex of A, and similarly on the other side, so that the two glandular rows *a b* are continuous with the two glandular rows *a' b'*, and we see that the cavity of the portion A or A' is formed by the bending over of the tube or horn B or B', with the partial absorption of the septum so formed between the tube and its bent-over part. If, then, we uncoil the curled up part of C, and separate the portion B on each side from the chamber C, we see that the so-called thyroid of *Ammocetes* may be represented as in fig. 3, *i.e.*, it con-

sists of a long common chamber C, which, for reasons apparent afterwards, I will call the *palæo-hysteron*, which opens by means of a large orifice into the respiratory or pharyngeal chamber. The anterior end of this chamber terminates in two tubes or horns B B', the structure of which shows that the median chamber C was composed by the amalgamation of two such tubes.

In the walls of each of these tubes is situated a continuous glandular line, the structure of the glandular elements being very characteristic in the length of the cells, in their large spherical nucleus situated at the very base of each cell, and in the way in which the cells form a wedge-shaped group, the thin points of all the wedge-shaped cells coming together so as to form a continuous line along the chamber wall. This free termination of the cells of the gland constitutes the whole method for the secretion of the gland: there is no duct, no alveolus, nothing but the free terminations of the cells in the lumen of the chamber. In the central chamber or *palæo-hysteron*, formed, as it clearly is, by the fusion of two such tubes, we naturally find this glandular line symmetrically situated on each side. Any explanation, then, of the thyroid gland of *Ammocetes* must take into account the clear evidence that it is composed of two tubes which have fused together in part to form an elongated central chamber, in part remain as horns to that chamber, and that in its walls there exists a line of gland cells of a striking and characteristic nature.

Further, this central chamber, with its horns, is not a closed chamber, but is in communication with the pharyngeal or respiratory chamber by three ways. In the first place, the central chamber, as is well known, opens into the respiratory chamber by a funnel-shaped opening, the so-called thyroid duct (Th. o). In the second place, there exist two ciliated grooves (Ps br, Ps br'), the pseudo-branchial grooves of Dohrn, which have direct communication with the thyroid chamber; the manner in which these grooves communicate with the thyroid chamber has never, to my knowledge, been described; it is very instructive, for, as I shall show, each groove enters into the corresponding lateral horn, so that, in reality, there are three openings into the thyroid chamber or *palæo-hysteron*, a median opening into the central chamber and a separate opening into each lateral horn.

The system of ciliated grooves on the inner ventral surface of

the respiratory chamber of *Ammocetes* was originally described by Schneider,¹ as consisting of a single median groove, which extends from the opening of the thyroid to the posterior extremity of the branchial chamber, and a pair of grooves, or semi-canal, which, starting from the region of the thyroid orifice, run headwards and diverge from each other, becoming more and more lateral, and more and more dorsal, till they come together in the mid-dorsal pharyngeal line below the auditory capsules. These latter are the pseudo-branchial grooves of Dohrn, of which I have already spoken in Part III. of this series of papers, and figured in Pl. III., Ps br.² Schneider looked upon the whole of this system as a single system, for he speaks of "a ciliated groove, which extends from the orifice of the stomach (*i.e.*, anterior intestine) to the orifice of the thyroid, then divides into two, and runs forward right and left of the median ridge, etc." Dohrn rightly separates the median ciliated groove posterior to the thyroid orifice from the paired pseudo-branchial grooves; the former is a shallow depression which opens into the rim of the thyroid orifice, while the latter has a much more intimate connection with the thyroid gland itself.

A series of sections, such as given in Pl. XLV., shows the relation of this pair of ciliated grooves to the thyroid better than any elaborate description. In the first place, it is clear that they remain separate up to their termination—they do not join in the middle line to open into the thyroid duct; in the second place, they are separate from the thyroid orifice—they do not terminate at the rim of the orifice, as is the case with the median groove just mentioned, but continue on each side on the wall of the thyroid duct, gradually getting further and further away from the actual opening of the duct into the pharyngeal chamber. During the whole of their course on the wall of the funnel-shaped duct they retain the character of grooves, and are therefore open to the lumen of the duct. The direction of the groove (Ps br) shifts as it passes deeper and deeper towards the thyroid, until at last, as seen in figs. 3 and 4, Pl. XLV., it is continuous with the narrow diverticulum of the turned-down single part of the thyroid (B), or turned-down horn, as I have called it. In other words, the median chamber opens into the pharyngeal or

¹ *Op. cit.*

² *This Journal.* vol. xxxiii. p. 154.

respiratory chamber by a single large funnel-shaped opening, and, in addition, the two ciliated grooves terminate in the lateral horns on each side, and only indirectly into the central chamber, owing to their being semi-canal, and not complete canals. If they were originally canals, and not grooves, then one would say the thyroid of the *Ammocetes* was derived from an organ composed of a large, common glandular chamber, which opened into the respiratory chamber by means of an extensive median orifice, and possessed anteriorly two horns, from each of which a canal or duct passed headwards to terminate somewhere in the region of the auditory capsule.

Dohrn has pointed out that a somewhat similar structure and topographical arrangement is found in *Amphioxus* and the Tunicates, the gland cells here being arranged along the hypobranchial groove to form the endostyle, and not shut off to form a closed organ as in the thyroid of *Ammocetes*. Dohrn concludes, to my mind rightly, that the endostyle in the Tunicates and in *Amphioxus* represents the remnants of the more elaborate organ in *Ammocetes*, and that, therefore, in order to explain the meaning of these organs in the former animals, we must first find out their meaning in *Ammocetes*. Dohrn, however, goes further than this; for just as he considers *Amphioxus* and the Tunicates to have arisen by degeneration from an *Ammocetes*-like form, so he considers *Ammocetes* to have arisen from a degenerated Selachian; therefore, in order to be logical, he ought to show that the thyroid of *Ammocetes* is an intermediate downward step between the thyroid of Selachians and that of *Amphioxus* and the Tunicates. Here it seems to me his argument utterly breaks down; it is so clear that the thyroid of *Petromyzon* links on to that of the higher fishes, and that the *Ammocetes* thyroid is an immeasurably more complicated and elaborate structure than that of *Petromyzon*, as to make it impossible to believe that the *Ammocetes* thyroid has been derived by a process of degeneration from that of the Selachian. On the contrary, the manner in which it is eaten up at transformation and absolutely disappears in its original form is, like the other instances mentioned, strong evidence that we are dealing here with an ancestral organ which is confined to the larval form, and disappears when the change to the higher adult

condition takes place. Dohrn's evidence, then, points strongly to the conclusion that the starting-point of the thyroid gland in the Vertebrate series is to be found in the thyroid of *Ammocœtes*, which has given rise on the one hand to the endostyle of *Amphioxus* and the Tunicates, and on the other to the thyroid gland of *Petromyzon* and the rest of the Vertebrata.

The evidence which I have just given of the intimate connection of the two pseudo-branchial grooves with the thyroid chamber shows to my mind clearly that Dohrn is right in supposing that morphologically these two grooves and the thyroid must be considered together. His explanation is that the whole system represents a modified pair of branchial segments distinct from those belonging to the VIIth and IXth nerves. The cavity of the thyroid and the pseudo-branchial grooves are therefore, according to him, the remains of the gill pouches of this fused pair of branchial segments, which no longer open to the surface, and the glandular tissue of the thyroid is derived from the modified gill epithelium. This view of Dohrn's, which he has urged most strongly in various papers, is to my mind right in so far as the separateness of the thyroid segment is concerned, but is not right, and is not proven, in so far as concerns the view that the thyroid gland is a modified pair of gills.

We may distinctly, on my view, look upon the thyroid segment, with its ciliated grooves and its covering plate of muco-cartilage, as a distinct paired segment, homologous with the branchial segments, without any necessity of deriving the thyroid gland from a pair of gills.

The evidence that such a median segment has been interpolated ventrally between the foremost pairs of branchial segments is remarkably clear, for the limits ventrally of the branchial segments are marked out on each side by the ventral border of the cartilaginous basketwork; and it is well known, as seen in fig. 1, that whereas this cartilaginous framework on the two sides meets together in the middle ventral line in the posterior branchial region, it diverges in the anterior region so as to form a tongue-shaped space between the branchial segments on the two sides. This space is covered over with a plate of muco-cartilage which bears on its inner surface the thyroid

gland. In addition to this evidence, that we are dealing here with a ventral tongue-like segment belonging to the facial nerve which is interpolated between the foremost branchial segments, we find the most striking fact that at transformation the whole of this muco-cartilaginous plate disappears, the remarkable thyroid gland of the *Ammocetes* is eaten up, and nothing left except a small, totally different glandular mass, and now the cartilaginous basketwork meets together in the middle line in this region as well as in the more posterior region; in other words, the striking characteristic of transformation here is the destruction of this interpolated segment, and the necessary drawing together ventrally of the branchial segments on each side.

Yet again, another most instructive piece of evidence pointing in the same direction is given by the behaviour of the ventral epithelial pits, as determined by Miss Alcock.¹ Although there is no indication on the ventral surface of the skin of any difference between the anterior and posterior portions of the respiratory region, yet when the ventral rows of the epithelial pits supplied by each branchial nerve are mapped out, we see how the most anterior ones diverge more and more from the mid-ventral line, exactly following out the limits of the underlying muco-cartilaginous thyroid plate.

The whole evidence strongly leads to the conclusion that the thyroid portion of the facial segment was inserted as a median tongue between the foremost branchial segments on each side, and that, therefore, the whole facial segment, consisting as it does of a thyroid part and a hyoid or branchial part, would be represented as in fig. 4, which is obtained by splitting an *Ammocetes* longitudinally along the mid-dorsal line, so as to open out the pharyngeal chamber and expose the whole internal surface. The facial segment is marked out by shading lines, the glosso-pharyngeal and vagus segments and the last of the trigeminal segments being indicated faintly. The position of the thyroid gland is indicated by oblique lines, C being the curled portion.

The problem of the thyroid gland reduces itself to this: In the ancestor of the *Ammocetes* the respiratory chamber was formed by a series of pairs of segments, each of which was

¹ This *Journal*, vol. xxxiii. p. 185, fig. 1.

branchial in function except the foremost pair, which carried the thyroid gland, and were not situated wholly bilaterally, but fused ventrally to form a single median segment. In accordance with the interpretation of the branchial segments already given, this median thyroid-bearing segment must have been origi-

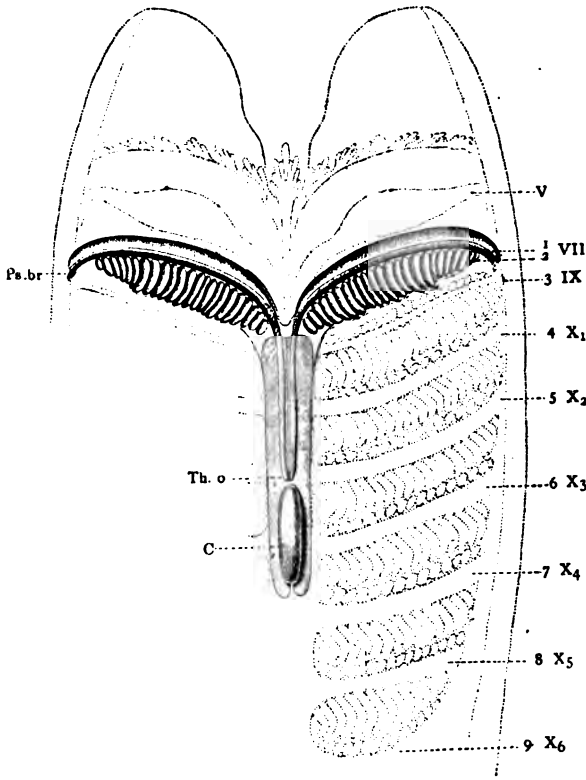


FIG. 4.—Facial segment of *Ammocetes* marked out by shading. VII. 1, thyroid part of segment; VII. 2, hyoid or branchial part; 3-9, succeeding branchial segments belonging to IXth and Xth nerves; V, the velar segment of Vth nerve; Ps. br., Dohrn's pseudo-brachial groove; Th. o., thyroid opening; C, curled portion of thyroid.

nally formed by the fusion of a pair of appendages, and from its position it must have been the foremost of the mesosomatic appendages; in other words, the operculum. Further, this median operculum was fused with the first pair of branchial appendages, which were arranged, like the rest of the branchial

appendages, bilaterally. In other words, if, as has been argued, the segments innervated by the IXth and Xth nerves were derived originally from the mesosomatic branchial appendages of an Eurypterus-like animal, then the segment innervated by the facial nerve would correspond to the opercular appendage of such animal, and consequently something of the nature of the thyroid gland of *Ammocetes* ought to exist in connection with the operculum of the *Limulus* and scorpion group.

THE OPERCULAR APPENDAGE OF THE SCORPION GROUP.

A survey of the nature of the opercular appendage demonstrates the existence of three different types :—

1. That of *Limulus*, in which the operculum is free, and carries only the terminations of the genital ducts; in this type the duct on each side opens to the exterior separately (fig. 5).

2. The type of *Scorpio*, *Androctonus*, *Buthus*, etc., in which the operculum is not free, but forms part of the ventral surface of the body wall, but, like *Limulus*, carries only the terminations of the genital ducts. In this type the duct on each side terminates in a common chamber (vagina or uterus), which communicates with the exterior by a single external median opening. This common chamber or uterus extends the whole breadth of the operculum (as seen in fig. 6), and is limited to that segment.

3. The type of *Thelyphonus*, *Hypoctonus*, *Phrynus*, etc., in which the operculum forms a part of the ventral surface of the body wall, but no longer covers only the termination of the genital apparatus, being double, its median anterior part covering the terminal genital apparatus, while its lateral posterior part covers the first pair of gills, or lung books, as they are called. In this type the genital ducts terminate in a common chamber or uterus, the nature of which will be further considered (fig. 7).

As has been pointed out by Blanchard,¹ the terminal genital organs of the scorpions and the Pedipalpi vary considerably in the different genera, especially the male genital organs. The general type of structure is the same, and consists in both male

¹ Blanchard, *L'organisation du Règne Animal*.

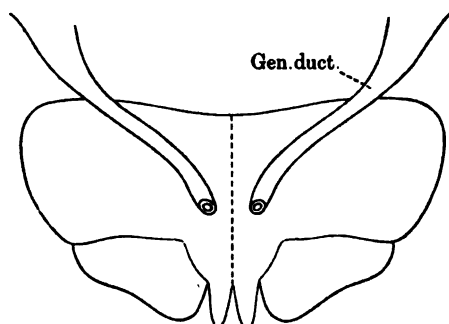


FIG. 5.—Operculum of *Limulus* to show the two separate genital ducts.

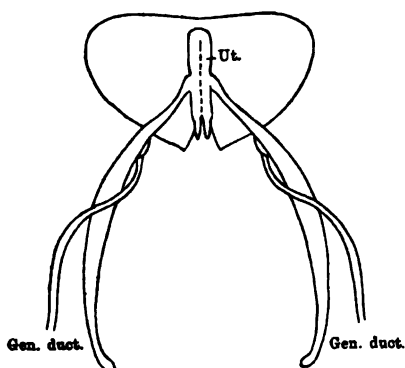


FIG. 6.—Operculum of male scorpion. Ut., terminal chamber.

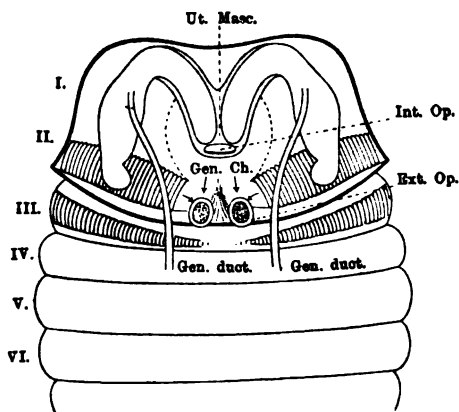


FIG. 7.—Operculum and following segments of male *Thelyphonus*. Opercular segment is marked out by thick black line. Ut. Masc., uterus masculinus; Int. Op., internal opening of uterus into genital chamber; Ext. Op., common external opening to genital chamber (Gen. Ch.) and pulmonary chamber.

and female of *vasa deferentia*, which come together to form a common chamber before the actual opening to the exterior. This common chamber has been called in the female scorpion the vagina, or in the Thelyphonus the uterus. I shall use the latter term, in accordance with Tarnani's¹ work, and the corresponding chamber in the male will be the *uterus masculinus*. The presence of a common chamber at all in the scorpions has been disputed by Dufour,² who says he has convinced himself that Duvernoy is wrong, and that there are two vulvæ and two vaginae. Ray Lankester³ speaks as though the existence of two separate tubes were a fact. Sections through the operculum show clearly that the single orifice opens into a single tube, the section of which is represented in fig. 10. Again, Dufour imagines that two tubes in the female correspond to two penes in the male, and he describes the peculiar chitinous rods which fill up the extraordinary channels of emission in the males of the scorpion group as penes (shown in fig. 6), which he supposes to be extrusible and capable of being inserted into the female vulvæ. In connection with this, he imagines an act of copulation in which the pectens interlocking are supposed to play a conspicuous part, but admits that no one has seen such a performance; chiefly, as far as I can gather from Dufour's imaginative sketch, the assertion has obtained currency in the text-books that the scorpions, like the phalangids, differ from the rest of the arachnids, in that they copulate by means of a penis, or rather a pair of penes, and not by some special modification of the pedipalps. Such is the description given by Pickard-Cambridge in the *Encyclopædia Britannica*, and by Lankester.⁴

It is so difficult to understand how these rods could possibly be extruded, as to justify one's hesitation in believing that they act as copulatory organs, without at all events very much stronger evidence than has been given up to the present time. Their position in the abdomen, the thickness of the chitinous

¹ Tarnani, "Die genital Organe der Thelyphonus," *Biol. Centralbl.*, vol. ix. p. 376, 1889.

² Dufour, *Institut de France, Acad. de Sciences; Mém. de divers savants*, vol. xiv. p. 645, 1856.

³ Ray Lankester, *Q. J. Micr. Sci.*, vol. xxi., 1881, p. 621.

⁴ Lankester, *loc. cit.*

rod in their interior, the insufficiency of such rod, even if it could be everted, as an organ for the transference of the spermatophores into the female vagina, all tend to make one hesitate. In *Thelyphonus*, *Hypoconus*, and other *Pedipalpi*, the corresponding rods are so hopelessly massive (fig. 7) that Blanchard confesses he cannot conceive how they can be extruded.

The evidence points to the conclusion that in all these forms the operculum covered a median single chamber or uterus, into which the genital ducts opened on each side, the male channels of emission being provided with a massive chitinous internal framework. We may feel certain that in the old extinct sea-scorpions, *Eurypterus*, etc., a similar arrangement existed, and that therefore in them also the median portion of the operculum covered a median chamber or uterus composed of the amalgamation of the terminations of the two genital ducts, which were originally separate as in *Limulus*.

The observations of Schmidt, Zittel, and others show that the operculum in the old extinct sea-scorpions, *Eurypterus*, *Pterygotus*, etc., belonged to the type of *Thelyphonus*, rather than that of *Limulus* or *Scorpio*. In fig. 8 I give a picture from Schmidt of the ventral aspect of *Eurypterus*, and by the side of it a picture of the isolated operculum. Schmidt¹ considers that there were five branchiæ-bearing segments constituting the mesosoma, the foremost of which formed the operculum. Such operculum is often found isolated, and is clearly composed of two lateral appendages fused together in the middle line, of such a nature as to form a median elongated tongue, which lies between and separates the first three pairs of branchial segments. This median tongue, together with the anterior and median portion of the operculum, concealed, in all probability, so Schmidt says, the terminal parts of the genital organs, just as the median part of the operculum in *Phrynos* and *Thelyphonus* conceals the complicated terminal portions of the genital organs. The posterior part of the operculum, like that of *Phrynos* and *Thelyphonus*, carried the first pair of branchiæ, so Schmidt thinks, from the evidence of markings on some specimens.

¹ F. Schmidt, "Die Crustaceen fauna der Eurypterschichten von Rootziküll auf Oesel," *Mém. d. l'Acad. Imp. d. Sciences de St Petersburg*, vol. xxxi. p. 28, 1883.

Apparently an opercular appendage of this kind is in reality a fusion of the genital operculum and the first branchial appendage of forms like the scorpion; for, in order that the tergal plates may correspond in number with the sternal in *Eurypterus*, etc., it is necessary to consider that the operculum is composed of two sternites joined together. Similarly with *Thelyphonus*, *Phrynus*, etc., correspondence only takes place when the operculum is looked upon as double.

A restoration of the mesosomatic region of *Eurypterus*, viewed from the internal surface, might be represented by fig. 9, in

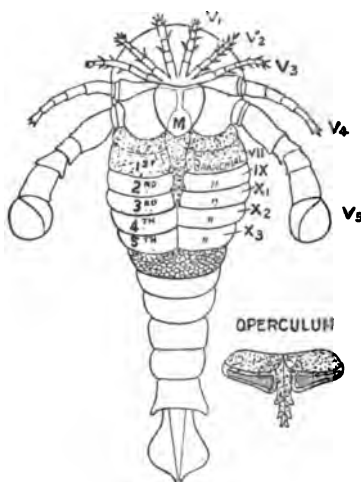


FIG. 8.—*Eurypterus* with isolated operculum. (After Schmidt.)

which the thick line represents the outline of the opercular segment, and the fainter lines the succeeding branchial segments. The middle and anterior part of the opercular segment carried the terminations of the genital organs; these I have represented, in accordance with our knowledge of the nature of these organs in the present-day scorpions, as a median elongated uterus, bilaterally formed, from which the genital ducts passed, probably as in *Limulus*, towards a mass of generative gland in the cephalic region, and not as in *Scorpio* or *Thelyphonus*, tailwards to the abdominal region.

The resemblance between this mesosomatic region of *Euryp-*

terus and that of *Ammocoetes* (fig. 14) is most striking, and gives a meaning to the facial nerve which is in absolute accordance with the interpretation already given of the glosso-pharyngeal and vagus nerves; in both cases the foremost respiratory or mesosomatic segment is double the posterior lateral part alone bearing the branchiæ, while the median and anterior part bore in the one animal the uterus and genital ducts, in the other the thyroid and ciliated grooves. The conclusion, therefore, to which we are driven is, that this extraordinary and unique organ, the so-called thyroid of *Ammocoetes*, which exists only in the larval condition, and is got rid of as soon as the adult

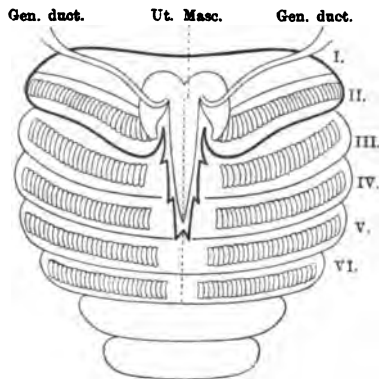


FIG. 9.—Diagram to indicate the probable nature of the mesosomatic segments of *Eurypterus*. The opercular segment is marked out by the thick black line. The segments II.-VI. bear branchiæ, and segment I. is supposed in the male to carry the uterus masculinus (Ut. Masc.) and the genital ducts.

sexual organs are formed, shows the very form and position of the uterus of the invertebrate ancestor of the *Ammocoetes*.

The strength of this conclusion will be greatly increased if the structure of the uterus in one or other of the present-day scorpions be found to resemble that of this thyroid of *Ammocoetes*; and seeing how striking is the arrangement and the structure of the gland tissue in the thyroid chamber, how unlike any other known glands except those already mentioned, we are searching for a tissue *sui generis*, and therefore unmistakable if found.

In the first instance, I examined the terminal parts of the genital ducts in *Limulus*, both in the male and female, but was

unable to discover any structure there at all resembling that of the thyroid of *Ammocoetes*. I then turned my attention to the organs of the scorpion, of which I possessed a considerable number, which were obtained from the morphological laboratory, and had been prepared excellently in the Neapolitan Biological Station. I there found that both in the male and in the female the genital ducts on each side terminate into a common chamber

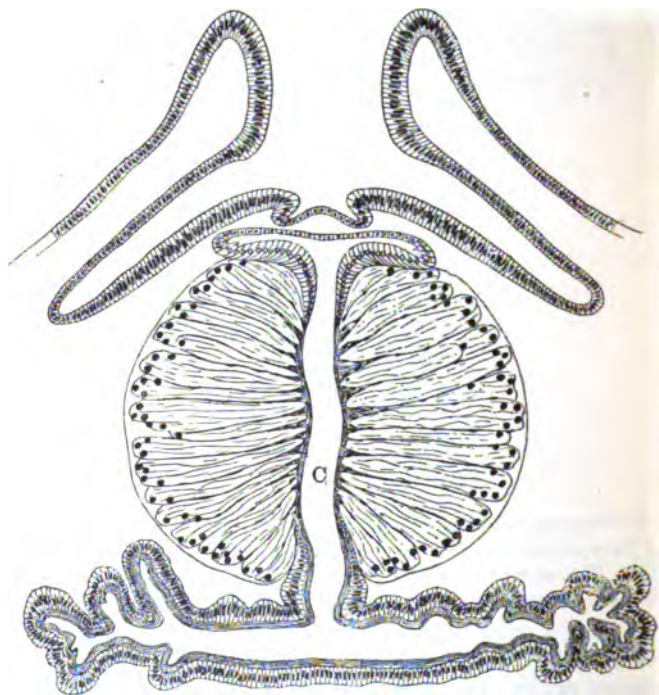


FIG. 10.—Section through the terminal chamber or uterus of the male scorpion. C, cavity of chamber. A portion of the epithelial lining of the channels of emission is drawn above the section of the uterus.

or uterus which underlies the whole length of the operculum, and opens to the exterior in the middle line, as shown in fig. 6. On transverse section, this uterus has the appearance shown in fig. 10, *i.e.*, it is a large tube, evidently expansible, lined with a chitinous layer and epithelial cells belonging to the chitinogenous layer, except in two symmetrical places, where the uniformity of the uterine wall is interrupted by two large remarkable

glandular structures. The structure of these glands is better shown by means of sagittal sections: they are composed of very long wedge-shaped cells, each of which possesses a large round nucleus at the basal end of the cell (fig. 11, p. 656); these cells are arranged in bundles of about eight to ten, which are separated from each other by connective tissue, the apex of each conical bundle being directed into the cavity of the uterus; where this brush-like termination of the cells reaches the surface, the chitinous layer is absent, so that this layer is, on surface view, seen (fig. 13) to be pitted with round holes over that part of the internal surface of the uterus where these glands are situated. Each of these holes represents the termination of one of these cone-shaped wedge of cells. If the section cuts across at right angles

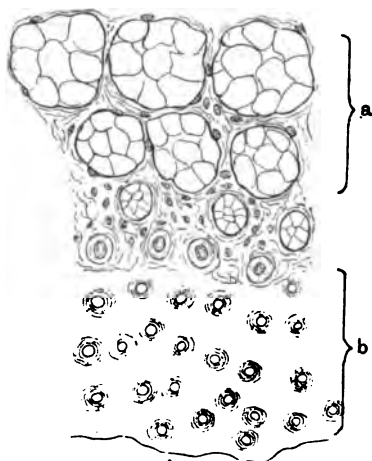


FIG. 13.—Sagittal section through the uterine gland of scorpion, showing the internal chitinous surface (*b*) and the glandular cones (*a*) cut through at various distances from the internal surface.

to the axis of these cones, then its appearance is represented in (*a*) fig. 13, and shows well the arrangement of the blocks of cells, separated from each other by connective tissue. When the section passes through the basal part of the cones, and only in that case, then the nuclei of the cells appear, often in considerable numbers in one section, as is seen in fig. 12, p. 656. In fig. 13 the section shows at *b* the holes in the chitin in which the cones

terminate, and then a series of layers of sections through the cones further and further away from their apices.

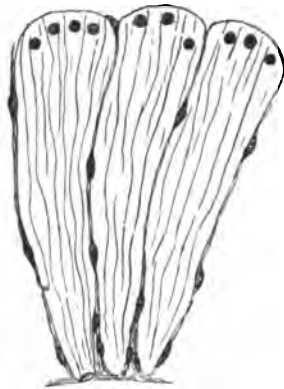


FIG. 11.—Longitudinal section through three of the cones of the uterine glands of the scorpion.

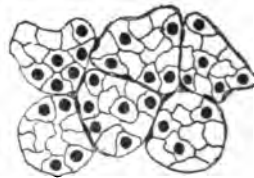


FIG. 12.—Transverse section through the basal part of the uterine glands of the scorpion.

These conical groups of long cells, represented in fig. 11, form on each side of the uterus a gland, which is continuous along its whole length, and thus forms a line of secreting surface on each side, just as in the corresponding arrangement of the glandular structures in the thyroid of *Ammocœtes*. This uterus and glandular arrangement is found in both sexes; the gland is, however, more developed in the male than in the female scorpion.

Most striking is the resemblance between the structure of the thyroid of *Ammocœtes* and the uterus of the scorpion, except in two respects, viz., the nature of the lining of the non-glandular part of the cavity—in the one case ciliated, in the other chitinous—and the place of exit of the cavity, the thyroid of *Ammocœtes* opening into the respiratory chamber, while the uterus of *Scorpio* opens direct to the exterior.

With respect to the first difference, it is on a par with the case of the ciliated tube of the central nervous system, which has already been discussed in Part I.¹ of this series of papers.

The second difference is more important, and is at first sight fatal to any comparison between the two organs. How is it possible to compare the uterus of the scorpion, which opens by

¹ This *Journal*, vol. xxxii. p. 537.

an external genital opening, to the thyroid of *Ammocœtes*, which opens by an internal opening into the respiratory chamber? However close may be the histological resemblance of structure in the two cases, surely such a difference is too great to be accounted for.

It is, however, to be remembered that the operculum of *Scorpio* covers only the terminal genital apparatus, and does not therefore resemble the operculum of the presumed ancestor of *Ammocœtes*, which, as already argued, must have resembled the operculum of *Thelyphonus*, with its conjoint branchial and genital apparatus, rather than that of *Scorpio*. Before, therefore, making too sure of the insuperable character of this difficulty, we must examine the uterus of the *Pedipalpi*, and see the nature of its opening.

The nature of the terminal genital organs in *Thelyphonus* has been described to some extent by Blanchard, and more recently by Tarnani.¹ The ducts of the generative organs terminate, according to the latter observer, in the large uterus, which is found both in the male and female; he describes the walls of the uterus in the female as formed of elongated glandular epithelium, with a strongly developed porous chitinated intima. In the male, he says that the epithelium of the uterus masculinus and its processes is extraordinarily elongated, the chitin covering being thick. In these animals, then, the common chamber or uterus into which the genital ducts empty, which, like the corresponding chamber in the scorpion, occupies the middle region of the operculum, is a large and conspicuous organ. Further, and this is a most striking fact, the *uterus masculinus* does not open direct to the exterior, but into the genital cavity, "which lies above the uterus, so that the latter is situated between the lower wall of the genital cavity and the outer integument." The opening, therefore, of the uterus is not external but *internal*, into the large internal space known as the genital cavity. The arrangement is shown in fig. 15, taken from Tarnani's paper, which represents a diagrammatic sagittal section through the exit of the male genital duct. Yet another most striking fact is described by Tarnani. This genital cavity is

¹ Tarnani, "Die genital Organe der *Thelyphonus*," *Biologischer Centralblatt*, vol. ix. p. 376, 1889.

continuous with the pulmonary or gill cavities on each side, so that instead of a single opening for the genital products and one on each side for each gill pouch, as would be the case if the arrangement was of the same kind as in the scorpion, there is a single large chamber, the genital chamber, common to both respiratory and genital organs.

This genital chamber, according to Tarnani, opens to the exterior by a single median opening between the operculum and the succeeding segment; similarly, a communication from side to side exists between the second pair of gill pouches. I have been

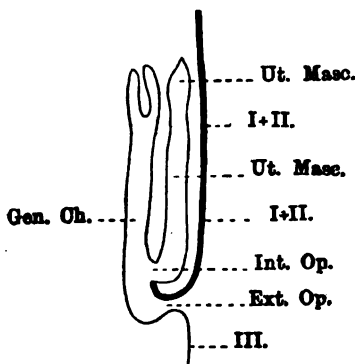


FIG. 14.—Sagittal median diagrammatic section through the operculum of the male *Thelyphonus* (from Tarnani). The thick line is the operculum, composed of two segments, I. and II. Ut. Masc., uterus masculinus; Gen. Ch., genital chamber; Int. Op., internal opening; Ext. Op., external opening common to the genital and respiratory organs.

able to examine *Hypoctonus formosus* and *Thelyphonus caudatus*, and in both cases, in both male and female, the opening to the exterior of the common chamber for respiration and for the genital products was not a single opening, as described by Tarnani in *Thelyphonus asperatus*, but on each side of the middle line, a round orifice closed by a lid, like the nest of the trapdoor spider, led into the common genital chamber (*Gen. ch.*) into which both uterus and gills opened. In fig. 7 I have endeavoured to represent the arrangement of the genital and respiratory organs in the male *Thelyphonus* according to Tarnani's and my own observations.

If we may take *Thelyphonus* as a sample of the arrangement

in those scorpions in which the operculum was fused with the first branchial appendage, as in the old sea-scorpions, then it is most significant that their uterus should open internally into a cavity which was continuous with the respiratory cavity, so that not only the structure of the gland but also the arrangement of the internal opening into the respiratory, or, as it became later, the pharyngeal cavity, and with that its whole developmental history, is in accordance with the suggestion that the thyroid of *Ammocetes* represents the uterus of the extinct *Eurypterus*-like ancestor. Into this uterus the products of the generative organs were poured by means of the *vasa deferentia*, so that there was not a single median opening or duct in connection with it, but also two side openings, the terminations of the *vasa deferentia*. These are described by Tarnani as opening into the two horns of the uterus, which thus shows its bilateral character, although the body of the organ is median and single; these ducts then pass within the body of the animal, dorsal to the uterus, to the testes or ovaries as the case may be; organs which are situated in these animals, as in other scorpions, in the abdomen, so that the direction of the ducts from the generative glands to the uterus is headwards. If, however, we examine the condition of affairs in *Limulus*, we find that the main mass of the generative material is cephalic, forming with the liver that dense glandular mass which is packed round the supra-oesophageal and prosomatic ganglia, and round the stomach and muscles of the head region; from this cephalic region the duct passes out on each side at the junction of the prosomatic and mesosomatic carapace to open separately on the posterior surface of the operculum, near the middle line, as is indicated in fig. 5.

We have therefore two distinct possible positions for the genital ducts among the group of extinct scorpion-like animals, the one from the cephalic region to the operculum, and the other from the abdominal region to the operculum.

The whole argument, so far, has in every case ended with the conclusion that the original scorpion-like form with which I have been comparing *Ammocetes* resembled in many respects *Limulus* rather than the present-day scorpions, and therefore in the case also of the generative organs with which the thyroid gland or *palæo-hysterion* were in connection, it is more probable

that they were cephalic in position rather than abdominal; if this were so, then the duct on each side, starting from the median ventral uterus, would take a lateral and dorsal course to reach the huge mass of generative gland lying within the prosomatic carapace, just as I have represented in the figure of *Eurypterus* (fig. 9), a course which would take much the same direction as the ciliated groove in *Ammocoetes*.

We ought therefore, on this supposition, to expect to find the remains of the invertebrate generative tissue, the ducts of which terminated in the thyroid, in the head region, and not in the abdomen.

As already pointed out in my paper in the *Quarterly Journal of Microscopical Science*,¹ the reason why the brain case of *Ammocoetes* is so much too large for its brain is given by the existence of a remarkable mass of glandular-looking substance which fills up the vacant space, and is present there, in my opinion, because it is the remnant of a pre-existing invertebrate glandular structure or structures which originally occupied this position. Such glandular structures, on the theory propounded in this series of papers, can be nothing else except the remains of liver and generative organs, which, as we know, form so great and conspicuous a mass round the cephalic region of the nervous system and alimentary canal of such animals as *Limulus* and its allies.

In that paper, in discussing this so-called 'arachnoidal tissue,' I referred entirely to the old liver, mainly because I was at that time discussing only the question of the liver; I have, however, from the very first, always compared this tissue with the whole glandular mass seen on removal of the prosomatic carapace in *Limulus*, *i.e.*, with a mass consisting of both liver cells and generative cells. The appearance of this tissue in *Ammocoetes* in position round the pineal eye, with its structure of large characteristic cells closely packed together, between which are situated here and there lines and masses of pigment, is given in figs. 20 a-20 d', Pl. xxvii. of that paper. Since writing that paper, the comparison of these cells with those of the so-called liver and of the generative glands of scorpions and other arachnids suggests strongly that they are the vestiges of the latter rather than the former glands. Thus Schimkewitsch's

¹ *Q. J. Micros. Sci.*, 1890, p. 26.

picture¹ of the generative gland of *Epeira* might almost have been drawn from this tissue, with the pigment lines left out. It is on the whole, I think, more probable that the generative gland cells should retain their form rather than cells like the so-called liver cells; with cessation of function it is quite conceivable, if not probable, that the latter should disappear, and their remains be represented only by the pigment masses and lines so characteristic of this tissue, while the former would still linger on, like the thyroid itself, because of the importance of the generative material to the wellbeing of an animal, apart from the excretion of its products. It is especially striking to see (*op. cit.*, fig. 13 c, pl. xxvi.) how thickly massed the pigment occurs at the place of the old liver duct, while the large cells are absent there.

I conclude, therefore, from the evidence of *Ammocoetes*, that the generative glands in the ancestral form were situated largely in the cephalic region, and suggest that the course and direction of the ciliated pseudo-branchial grooves on each side indicate the direction of the original opercular ducts by which the generative products were conveyed to the uterine chamber, *i.e.* to the chamber of the thyroid gland, and from thence to the common genital and respiratory cavity, and so to the exterior.

It is easy to picture the sequence of events: first the generative glands, chiefly confined to the cephalic region, communicating with the exterior by separate ducts on the inner surface of the operculum as in *Limulus*; then, in connection with the viviparous habit, these two oviducts fused together to form a single chamber, covered by the operculum, which opened out to the exterior by a single opening as in *Scorpio*; or in forms like *Eurypterus*, in which the operculum had amalgamated with the first branchial appendage, and possessed a long tongue-like ventral projection, the amalgamated ducts formed a long uterine chamber which opened internally into the genital chamber,—a chamber which as in *Thelyphonus* was common with that of the two gill chambers, while at the same time the genital ducts from the cephalic generative material opened into two uterine horns which arose from the anterior part of the uterus, as in *Thelyphonus*.

¹ *Annales de S. i. naturelle. Zoologie*, vol. xvii., 1884,—“*Anat. de l'Epeire*,” pl. 6, fig. 8.

Such an arrangement would lead directly to the condition in *Ammocetes*, if the generative material around the brain lost its function, owing to a new exit for generative products being formed in the posterior part of the body. The connection of the genital duct with this cephalic gland being then closed and cut off by the brain case, the position of the oviducts would still be shown by the ciliated grooves opening into the folded-down thyroid tube, *i.e.*, the folded-down horns of the uterus; the uterus itself would remain as the main body of the thyroid, and still open by a conspicuous orifice into the common respiratory chamber. Next in the degeneration process we may suppose that not only the oviducts opened out to form the ciliated groove, but also the uterine chamber itself, and thus formed the endostyle of *Amphioxus* and of the Tunicates.

It seems at first sight unlikely that a closed tube should become an open groove, although the reverse phenomenon is common enough; however, the difficulty is clearly not considered great, for it is precisely what Dohrn imagines to have taken place in the conversion of the thyroid of *Ammocetes* into the endostyle of *Amphioxus* and the Tunicates; it is only carrying on the same idea yet a stage further to see in the open ciliated groove of *Ammocetes* the remains of the closed genital duct of *Limulus* and its allies. On the other hand, both Blanchard and Tarnani describe a grooved channel on the wall of the male uterus, which they think helps to carry the sperm. It is possible that this ciliated groove was always an open groove, and that, although belonging to the genital apparatus, it played only a subsidiary part in the passage of the sperm, as in the open groove of *Thelyphonus*.

Such is the conclusion to which the study of the thyroid gland in *Ammocetes* seems to me to lead, and one cannot help wondering why such an unused and rudimentary organ should have remained after its original function had gone; is it possible to find out its function in *Ammocetes*?

FUNCTION OF THYROID.

Topographically and structurally, we see that the thyroid of *Ammocetes* corresponds to the uterus of the scorpion group, and the question arises, why should this organ have remained up to

the stage of *Ammocoetes* in so perfect a condition; is there any reason given by the examination of its function?

It is asserted by Dohrn, on the authority of Fol, that the corresponding cells of the Tunicate endostyle secrete mucus, and that the ciliated cells are for the purpose of passing on the food mixed up with this mucous secretion. For this reason he concludes that the thyroid gland cells of *Ammocoetes* are for a similar purpose, namely, the secretion of mucus, in order to aid in the passage and digestion of food along the pharyngeal chamber. In a foot-note he expressly states that he at first dissented from Schneider's assertion that these cells were mucus-secreting, and confesses his error, as subsequent investigation has shown him that they do secrete mucus (*op. cit.*, p. 48). Beyond this bare statement, I have been unable to find any description in Dohrn's writings of the nature of the evidence which caused him to alter his mind on this matter. The insufficiency and weakness of Schneider's evidence is commented on in Miss Alcock's paper, and need not be reasserted here. I can only say that after the examination of many specimens in the full-grown *Ammocoetes*, both by Miss Alcock and myself, we have been surprised with the entire absence of any evidence of any secretion of any kind whatever in the cavity of the thyroid chamber; while at the same time, as she points out in her paper, the mucous secretion from the glandular cells of the branchiæ is always most evident, and can be most easily seen, even in the cells themselves, when the tissue is stained by hæmatoxylin, or better still, by thionin and other basophil dyes. Not only is there no evidence of any mucous secretion in the thyroid of the fully developed *Ammocoetes*, but also no necessity for such secretion from Dohrn's point of view, for so copious a supply of mucus is poured out by the glands of the branchiæ, along the whole pharyngeal tract, especially from the cells of the foremost or hyoid gills, as to mix up with the food as thoroughly as can possibly be needed; further, too, the ciliated pharyngeal bands described by Schneider are amply sufficient to move along this mixed mass in the way required by Dohrn. Finally, the evidence given by Miss Alcock is dead against the view that the thyroid takes any part in the process of digestion; while, on the other hand, her evidence directly favours the view that these

glandular branchial mucus-secreting cells play a most important part in the digestive process.

In fig. 15 (drawn by R. Alcock), A is a representation of the respiratory tissue of a normal gill ; B is the corresponding portion of the 1st or hyoid gill, in which, as is seen, the whole of the respiratory epithelium is converted into gland tissue.

To sum up, the evidence is clear and conclusive that the *Ammocoetes* possesses in its pharyngeal chamber mucus-secreting

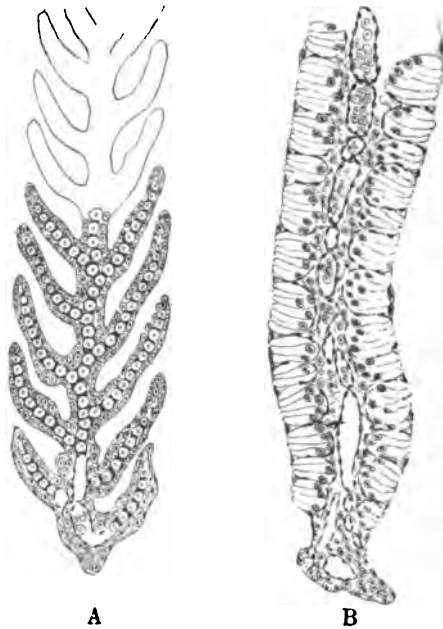


FIG. 15.—A, portion of a gill of *Ammocoetes* with ordinary respiratory epithelium ; B, corresponding portion of the 1st or hyoid gill.

glands, which take an active part in the digestion process, which do not in the least resemble either in structure or arrangement the remarkable cells of the thyroid gland, and that the experimental evidence that these latter cells either secrete mucus or take any part in digestion is so far absolutely negative. It is, of course, possible, and indeed probable, that they contain mucin in the younger stages, and therefore possible that they might secrete it ; they certainly, however, show no sign of it in their more adult

condition, and cannot be compared in the very faintest degree to the glandular cells of the pharyngeal region.

It is also perfectly possible for gland cells belonging to a retro-grade organ to become mucus-secreting, and so to give rise to the cells of *Amphioxus* and the *Tunicata*.

If, then, these cells were not retained for digestive purposes, what was their function? To answer that question we must first know the function of the corresponding gland cells in the uterus of the scorpion, which undoubtedly secreted into the cavity of the uterus, and took some part in connection with the generative act, and certainly not with digestion. What was the function of these cells, whether they secreted some cement substance or whether they are purely excretory in function, or in what way they acted, I am unable at present to say. I can only suppose that the reason why the thyroid gland has persisted throughout the Vertebrate kingdom, after the generative tissues had found a new outlet for their products in the body cavity of the posterior region, is because it possessed some important function in addition to that connected with the exit of the products of the generative organs; a function which was essential to the wellbeing or even to the life of the animal. We do not know its function in the scorpion, or the nature of its secretion in that animal; we know only that physiology at the present day has demonstrated clearly that the actual external secretion of a gland may be by no means its most important function; in addition, glands possess what may be called an internal secretion, viz., a secretion into the blood and lymph fluids, and this latter secretion may be of most vital importance. Now, the striking fact forces itself prominently forwards, that the thyroid gland of the higher vertebrates is the most conspicuous example of the importance of such internal secretion. Here, although ductless, we have a gland which cannot be removed without vital consequences. Here, in the importance of thyro-iodine, we have a reason for the continued existence of this organ; an organ which we can trace down to its condition in *Petromyzon*, and then with a sudden jump we pass to the more elaborate, more extensive organ of *Ammocetes*. Surely we may argue that it is this second function which has kept it going, and that its original form without its original

function is seen in *Ammocetes*, because that is a larval form, and not a fully developed animal. As soon as the generative organs of *Petromyzon* are developed at transformation, all trace of its connection with a genital duct vanishes, and presumably the thyro-iodine function alone remains.

Such, then, is the conclusion to which the study of the thyroid gland in *Ammocetes* leads, viz., that the facial nerve was originally the nerve of an operculum, which was itself composed of two segments, the posterior of which was branchial. Such operculum formed the most anterior of the mesosomatic or respiratory appendages, so that the facial nerve must be classed definitely with the branchial or opisthotic group of cranial nerves, and not with the pro-otic. Further, the fact that such an operculum represents two segments fused together, points to the conclusion that the facial nerve originally supplied two segments, in harmony with v. Wijhe's suggestion.

Again, it is significant that in so many forms, such as *Thelyphonus*, etc., one segment, and one only, posterior to the opercular segment, should bear branchiæ which would, in the language of Vertebrate anatomy, mean that the branchial nerves were in these cases confined to the facial and glosso-pharyngeal, while in other cases, such as *Scorpio*, *Limulus*, etc., a number of segments, either 4 or 6, are branchiæ-bearing; such a fact may ultimately be found to give an explanation of the peculiar fact that in all vertebrates the glosso-pharyngeal is an isolated, typically branchial nerve, supplying a segment between the hyoid and the vagus segments, even in *Ammocetes*, where there is absolutely no difference between the second branchial or glosso-pharyngeal segment and any one of the following vagus segments, yet the glosso-pharyngeal is an isolated nerve with an isolated ganglion, and does not form a part of the nerve complex, which is fused together to form the vagus.

FORMATION OF ANTERIOR OR RESPIRATORY PORTION OF ALIMENTARY CANAL IN VERTEBRATES.

The logical following out of the theory that the brain region of the vertebrate is derived from the combined brain region and cephalic part of the alimentary canal of the original arthropod ancestor, has led us to the conclusion that the anterior portion

of the vertebrate alimentary canal was originally a respiratory chamber, formed largely by the mesosomatic respiratory appendages, and originally closed in front anteriorly by the operculum. Such a chamber had originally no part in digestion, and did not communicate with the mouth; at this stage, if an alimentary tube existed ventral to the central nervous system, I should suppose it to have been the notochordal tube, which is generally supposed to have been once patent, and to have acted as an alimentary canal. Then came the formation of an oral chamber by the forward growth of the lower and upper lips, as seen in *Ammocoetes* (Dohrn,¹ figs., vol. 6). In this way a new mouth chamber was formed, to which the name of stomatodæum has been given; it is, however, in reality not formed by any invagination, but by the outgrowth of the lower and upper lips, especially the lower lip. This oral chamber formed the new vertebrate mouth cavity, and was separated from the respiratory chamber by the so-called septum of the stomatodæum. The breaking down of this septum, which occurs late in embryonic life, brought the two chambers into connection; and now, through the new mouth, not only water of respiration, but also food mixed in that water, could find its way into the large respiratory, or as it may now be called, pharyngeal cavity.

According to this conclusion, we see that of the two functions of the anterior part of the alimentary canal of the vertebrate, viz., alimentation and respiration, the latter is the more primitive; and that, contrary to what is usually taught, the vertebrate alimentary canal is formed from a pre-existing respiratory chamber, and not that the respiratory apparatus is derived from a pre-existing alimentary canal. It is a striking fact that in the life-history of *Petromyzon*, the anterior portion of the alimentary canal should be at first so markedly respiratory in function, and that then, when transformation occurs, an absolutely new alimentary tube should be formed in this portion of the alimentary tract. This formation of a new digestive tube by the hollowing out of a solid rod of cells situated in the substance of the dorsal ridge, as described originally by Schneider and confirmed by all other observers, is one of the most extraordinary phenomena among the many startling changes

¹ Dohrn, *op. cit.*, taf. 5, figs. 9, 10, 11.

seen in this animal at transformation ; and when we see how, again and again, the transformation process is associated with the casting off of Invertebrate characteristics, and the putting on of the attributes of a higher type, it looks as though, in the Invertebrate stage, this part of the alimentary canal was formed for respiration rather than alimentation, and that in the passage to a higher type it was advantageous to separate off a channel for alimentation, so as to leave the respiratory chamber free. It demonstrates also in a striking manner the ease with which an animal can manufacture a new food channel.

If, however, this portion of the alimentary canal of *Ammocoetes* owes its origin to what was originally a respiratory chamber, how is it possible to conceive that its epithelium should have taken on the power of digesting food? Is it not making too great a demand upon our credulity to suppose that respiratory appendages clothed with ectoderm should be able to form digestive ferments just like endodermal surfaces, simply because they happen to have become internal? No difficulty would arise if it was simply a question of an amylolytic ferment, for this is known to be present more or less in all the tissues of the body, but it is very different with the proteid digestive ferments. The formation of trypsin and pepsin is essentially the function of gland tissues in connection with the alimentary canal, and in all the higher Vertebrates these ferments are formed by special glands in special places, usually the stomach and pancreas. As we descend in the Vertebrate series, we find from the labours of Krukenberg, as sketched out in Miss Alcock's paper, that this digestive power is spread over a wider area, and finally in *Ammocoetes* digestion occurs, not only in the liver, but also in the pharyngeal chamber, owing to the presence of glandular epithelium at the base of the branchial appendages. In fact, the lining of the pouches between the branchial appendages, where mud and food collects to a certain extent, is modified into a secreting surface, by which presumably peptic digestion is in part carried on. During transformation, when the solid rod of cells forming the new œsophagus completely blocks the passage from the branchial chamber to the intestine, the only possibility of any digestion and absorption of food is in this branchial chamber. If we may judge from the observations

of Shore,¹ the liver of the Vertebrate is not morphologically the same as the liver of the Crustacean; and seeing that in *Amphioxus* it is a simple diverticulum of the intestine, it seems reasonable to suppose that a diverticulum of active tissue, such as is found in the pharynx, should have formed the liver of the *Ammocoetes*, and so give rise to its digestive power, as shown by Miss Alcock's experiments.

Finally, her work has solved in the most satisfactory and unexpected manner the question how to imagine the initial formation of digestive glands in a chamber formed largely by the respiratory appendages; for she has shown that the ectodermal cells of the *Ammocoetes* secrete a fluid which is capable in the presence of an acid of digesting fibrin, so that it becomes perfectly natural and simple for such a surface covering the bases of the respiratory appendages to form the commencement of an efficient digestive canal.

I do not suppose that this skin secretion was formed in the arthropod ancestor, or in the *Ammocoetes*, for the purpose of digesting food, but rather, as Hardy's experiments² render very probable in the case of a similar secretion from the surface of *Daphnia*, the secretion is for the purpose of keeping the surface clean; it is protective, in its original conception, against microscopic spores of all kinds, infusorians, etc., and it is to my mind a very significant fact that such a protective secretion should contain a proteid-digesting ferment, or at all events a zymogen which is capable, in the presence of an acid, of forming such a digestive ferment.

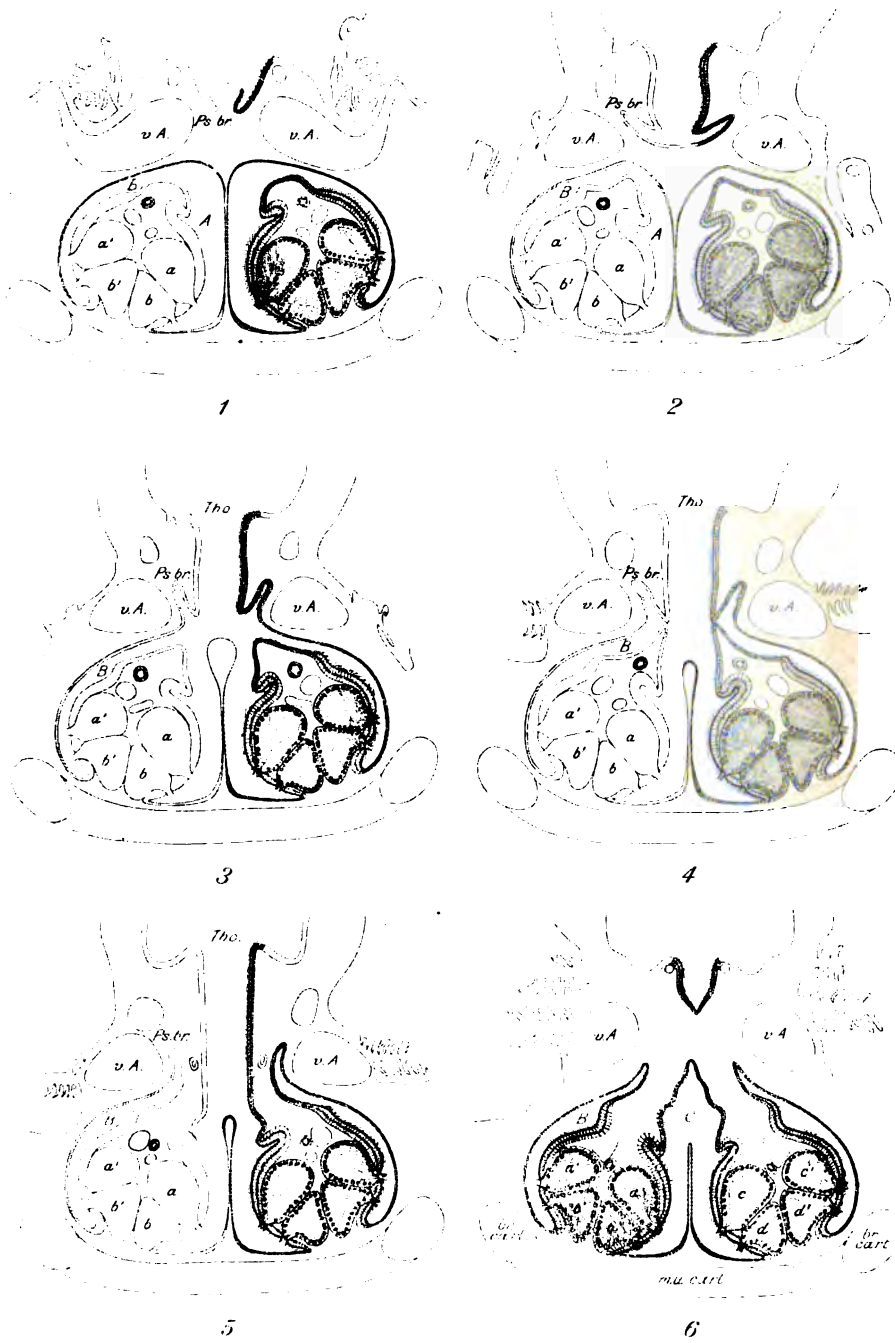
I have been able to test the truth of this protective theory in the case of *Petromyzon fluviatilis*, which is easily obtainable in the spring-time of the year in a river near Cambridge. In the first place, Miss Alcock found that the skin of this animal possessed digestive powers of the same kind as that of *Ammocoetes planeri*; and in the second place, we found that all the specimens when taken out of the water were perfectly clean and free from fungus growths. It so happened that the fisherman who was collecting for me had accumulated a large quantity in a wooden

¹ This *Journal*, vol. xxv. p. 166.

² "The protective functions of the skin of certain animals," *Journ. of Physiol.*, vol. xiii., 1892, p. 309.

live-bait box, through which the river water ran, and they remained in this box some days before I was able to come and fetch them away. Owing to the want of space, they had not only sucked on to the sides of the bait box, but also to each other, with a result that a round patch of epithelium had been denuded at the place of attachment. Most of these bare patches were covered over with a luxuriant fungus growth, while, wherever the skin was intact and the epithelium good, the surface was as clean as in those freshly taken out of the river. In order to make certain that the removal of the epithelial cells was the cause of the growth of fungus, I removed, by gently scraping, patches of epithelium from the skin of two of the lampreys which I had brought to Cambridge, and which were free from fungus. Upon putting them into the same aquarium with some of the infected lampreys, fungus began also to grow on the spots from which I had denuded the epithelium.

Such, then, appears to me the probable manner in which the original cavity formed for respiratory purposes became converted into a digestive as well as a respiratory tube, and it is worth pointing out that the epithelium of the uppermost respiratory segments has specially become converted into glandular epithelium, so that in the hyoid segment, supplied by the VIIth nerve, nearly the whole of the epithelium has become glandular (fig. 15), while in the next segment, supplied by the glosso-pharyngeal, a considerable extent of gland cells has become developed. Whether this special glandular development in the segments innervated by the VIIth and IXth nerves has any connection with the digestive glands of the higher vertebrates, which are also innervated by these two nerves, viz., the submaxillary and parotid glands respectively, I cannot attempt to decide. The fact that these glands are innervated by such purely branchial nerves as the facial and glosso-pharyngeal has always seemed to me to point to the possibility, if not probability, of their origin from some part of the two foremost branchial segments.



DESCRIPTION OF FIGURES, PLATE XLV.

These figures are drawings of transverse sections through the anterior part of the thyroid gland of *Ammocoetes*. They are samples taken from a complete series, in order to show the connection of the ciliated groove Pa br with the lateral tube B of the thyroid. Sections 1 and 2 are anterior to the thyroid opening Th. o. Sections 3, 4, and 5 are through the thyroid opening, and section 6 is posterior to the thyroid opening before the commencement of the curled part.

The letters A B C refer to the corresponding letters in fig. 2.

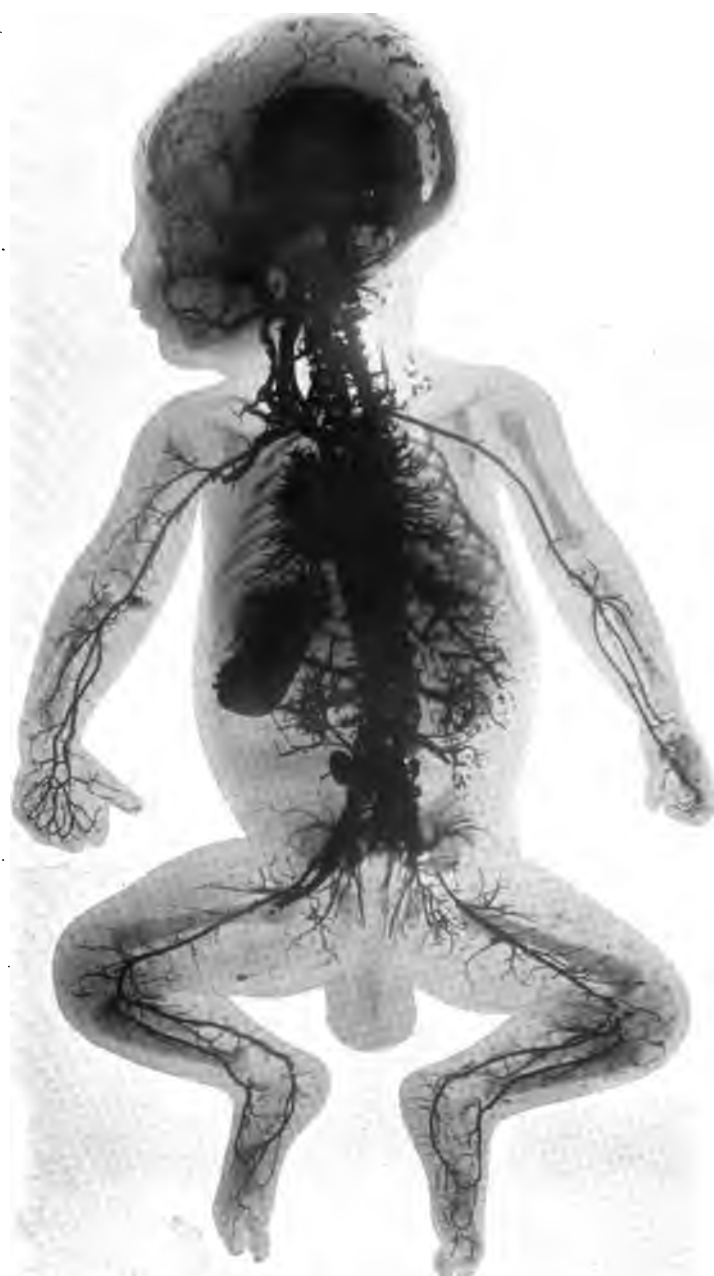
v.a., ventral aorta ; br. cart., branchial cartilage ; mu.-cart., mucocartilage.

A RADIOGRAPH OF AN INJECTED FULL-TERM FŒTUS

(taken by MR F. H. GLEW, Member of the Röntgen Society).

By CHARLES IND. MUSGROVE, *Scholar in Anatomy and Physiology, St Thomas' Hospital.* (PLATE XLVI.)

IN previous injections of parts of the human body and of various animals, several different fluids have been used, such as lead, oxide, and bismuth, nitrate or carbonate, in a state of suspension in water, and also mercury in the metallic state in cases where the tissues were sufficiently resistant. In my first attempt at injecting a foetus (bearing in mind that the opacity of the result is directly proportionate to the atomic weight of the element used), I used bismuth nitrate, 17 per cent., suspended in water by means of tragacanth, a little arsenious acid being previously dissolved in the water as an antiseptic. Such an injection has the disadvantages (*a*) that it tends to clog the syringe and to subside in the tissues; (*b*) that a moderately large syringe must be used, and therefore that only a large artery, such as the carotid or aorta, can be successfully injected by it; (*c*) that the smaller vessels frequently escape injection altogether. I, however, made a window in the thorax, and injected the arch of the aorta with about eight fluid ounces of the bismuth compound; a radiograph was then taken, and it was at once evident that the opacity of this fluid is greater than that of the lead injections so often used, all the large vessels coming out with great distinctness, but the smaller arteries, such as the digitals and intercostals, did not show at all. At the suggestion of Mr Glew, who indeed first broached the subject of attempting to inject a foetus to me, I tried a second experiment, using mercury instead of bismuth, with the result shown in the accompanying radiograph. This fluid was introduced by means of a hypodermic needle, connected by stout rubber-tubing to a glass funnel capable of holding two fluid ounces, and elevated above the level of the needle to a height of five inches, in a suitable holder, which could be elevated or depressed, thus raising or lowering the pressure of mercury:



RADIOGRAPH OF AN INJECTED FULL-TERM FŒTUS.

the whole was then filled with mercury, to exclude air, and securely clamped. The external circumflex branch of the femoral artery was next dissected out, the needle introduced into it, the clamp removed, and in this way about four pounds of mercury by weight were passed into the arterial system of the child; the artery was then ligatured, and the incision closed by a stitch. It is most important in such cases that the radiograph should be taken immediately the injecting is finished, as the mercury tends to gravitate back to the lowest level, and unfortunately in this case a delay occurred in the arrival of the plate, and the intercostal arteries, with some others, which were readily seen on the screen at the time of injection, do not, for this reason, appear in the radiograph shown. The aorta, left side of the heart, kidneys, and spleen are readily recognisable, the spleen especially so, and the vessels of the neck and extremities are all that can be desired: the results were checked in a post-mortem by Dr Gillanders. Some mercury did pass through the foramen ovale into the right internal jugular vein and lateral sinus; no other veins contained any, however. Lastly, I attempted to improve the result by elevating the funnel four inches higher; this, unfortunately, caused the intestinal vessels to give way, and extensive bursts occurred in the abdominal cavity. The subject was arranged on a piece of thin cardboard over the photographic plate ("Thomas' A1"). The focus tube was fixed over the centre of the plate, with the radiant point twenty-four inches from the same; an exposure of twenty minutes was given, with a current of three amperes through a 10-inch Apps' coil. All the radiography was done by Mr Glew, of Clapham.

A RARE FORM OF PALATAL SUTURE.

By Professor Sir WM. TURNER.

IN a communication printed in the *Journal of Anatomy and Physiology*, vol. xix. p. 198, I discussed the relation of the alveolar form of cleft palate to the incisor teeth and the intermaxillary bones. The paper was written in relation to the view put forward by Paul Albrecht, that each intermaxilla consisted of two elements, a mesial (endognathial) separated from a lateral by an intermediate suture, which disappears in an early stage of development; whilst the lateral was separated from the superior maxilla by the maxillo-premaxillary suture, which extends to the alveolar border of the upper jaw to the interval between the outer incisor and the canine tooth.

I have recently examined an adult female skull, apparently that of a European, in which a suture existed in the anterior part of the right half of the hard palate, but which had unusual relations to the alveolar border of the jaw. It began at the hinder part of the anterior palatine fossa and curved outwards, with its concavity forwards, to the alveolar border of the upper jaw, which it reached opposite the interval between the canine and first bicuspid tooth, where it disappeared from view. The margins of the suture showed a few very short denticulations.

If this suture is to be regarded as the maxillo-premaxillary suture, the premaxilla in this skull carried the canine tooth as well as the two right incisors; our conception of the relations of the premaxilla to the teeth would, so far as this specimen is concerned, require to be extended, so as to include the canine tooth as one of its dentary elements in addition to the incisors.

A careful inspection of the palate in front of this suture showed a groove, deepened almost into a narrow cleft, which passed forwards from the suture about midway in its length, and reached the alveolar border at the outer part of the socket of the lateral incisor. It is possible that this may have been only a vascular groove; but if it represented a true suture, it

would then be the proper maxillo-premaxillary suture, and the premaxilla would be carrying only the incisor teeth. The part of the jaw, with the alveolus in which the canine tooth was lodged, would then have to be regarded as a separate element, interposed between the premaxilla and the superior maxilla with its bicuspid and molar teeth.

Whichever of these two views be accepted, the ossification of the upper jaw presented in this skull an interesting departure from the normal arrangement.

No appearance of a maxillo-premaxillary suture was visible on the facial aspect of the upper jaw. No vestige of this suture could be seen on the palatal surface of the left upper jaw, except a slight trace at the anterior palatine fossa. The hard palate was deeply arched and, for a European, long in relation to its breadth. The palato-maxillary length was 50 mm., the breadth in the plane of the 2nd molars was 53 mm., and the index was 106; the skull in this region comes, therefore, into the group which I have named dolichuranic in my classification of skulls according to the proportions of the alveolo-palatine arch (*Challenger Reports*, part xxix., 1884). The teeth were erupted, and normal in number and relative position.

I am indebted to my assistant, Mr James Simpson, for this interesting cranium.

ARCHÆOLOGIA ANATOMICA.

V.

TENDO ACHILLIS.

THERE is a classical sound and a presumption of antiquity connected with the name of this structure; yet the examination of the literature of anatomy shows that this eponym is of comparatively late origin, and of equivocal significance. Hippocrates knew of the "great chord," but not of tendo Achillis; and Celsus, Galen, Ruffus, and Pollux are also ignorant of the name. It does not occur in the works either of the classic lexicographers nor of the mediæval translators.

The first correlation of this tendon with the name of Achilles known to me is in the writings of Vesalius (1543), who, on p. 246, when describing the tendon of the calf-muscles, points out that, on account of the projection of the heel behind the level of the tibia, this tendon is thrown backwards, and forms with the tibia a triangle whose base is the length of the calcaneal projection, and on each side of the tendon there is a lateral concavity. "Atque hæc ea demum est cavitas, cui Homerus Achillem in Hectoris crure funem traiecisse, illumque ad currum religatum, circum moenia Troiæ traxisse cecinit."

His contemporary Columbus (1559) also refers to this in the words "*Cum Hector raptaretur hoc tendine vinctus fuisse dicatur*," referring to the familiar passage in *Iliad* xxii. 396:

Ἀμφοτέρων μετόπισθε ποδῶν τέτρηγε τένοντε
Ἐς σφυρὸν ἐκ πτέρυγης, βοέους δ' ἐξήπτεν ἱμαντας,
Ἐκ δίφρουο δ' ἔδησε.

Valverduus in 1607, writing, not of the tendon but of the concavity between it and the ankles, says "*quo etiam Pelides apud Homerum alligatum Hector circum Troiæ moenia raptasse fertur*." The story crystallised around the tendon, and by 1645 we find in this connexion that Spigelius says "*hic ille est tendo quo*

Hectorem Achilles circum Troiæ mœnia traxisse Poëtarum maximus canit."

With Bauhin in 1588 another story begins; "*Achilles hoc tantum parte mortalis erat.*" But not yet has the structure been definitely named tendo Achillis, for of the succeeding writers, Laurenti (1600), Veslingius (1647), Cowper (1694), Blancard (1695), Cheselden (1721), and many others do not use the name. The tuneful Sponius, had he known the name, would surely have introduced it into his metrical myology, but instead he disposes of these muscles thus:—

*Tres reliqui validam confuso tendine chordam,
Ad talos conflant quæ pollet acumine sensûs;
Gasterocnemius internus nec robore dispar
Gasterocnemius exterior, Soleusque propinquus.*

Also in his "*Musculorum Microcosmi origo et insertio*":—

*Tendo utrinque tendini
Solii lacerti unitus in calcem facit,
Insertionem splendidam.*

One is inclined to ask digressively here what there is in myology to induce authors to seek a poetical method of expression? Not only have we these two works of Sponius, but there is the "*Myographia heroïcæ versu explicata*" published by Quarré at Frankfort in 1670, and also the "*Quatrains Anatomiques des os et des Muscles*" published in French by Bimet at Lyons in 1664.

The name became finally established by the beginning of the 18th century. Verheyen says "*vocatur passim chorda Achillis*" in 1710, and Winslow in 1732 calls it the tendon of Achilles or the cord of Hippocrates.

We have seen that there were two stories to account for the association of Achilles with the tendon, that given by Vesalius and that by Bauhin. The veteran anatomical onomatologist Hyrtl pronounces decidedly in favour of the latter, but there are grave reasons to doubt this. First, the older authors Vesalius and Columbus are both in favour of the Hector story, and ignore the other, as also do the 17th century writers who profess to

be classical scholars; and secondly, while the Hector story is Homeric, the legend of the dipping of the infant Achilles in the Styx is not only not Homeric, but is comparatively late in its origin. The oldest writer who gives it is Statius, who died about A.D. 96, and it was probably also mentioned by his contemporary Hyginus, at least it is quoted from him in Fulgentius (A.D. 550), *Fab.* iii. 7. Apollonius Rhodius (*Argonautic.* iv. 868 ff.) certainly gives some account of his being made invulnerable by fire and water, but makes no mention of the Styx. Horace (*Epod.* xiii.) merely calls him *invictus*, Ovid (*Met.* xii.) also speaks of the fatal shaft as directed by the deadly right hand of Apollo, and Virgil uses much the same words (*Æn.* vi. 57), but it is only his commentator Servius who imports into his narrative the myth of invulnerability; while other authors speak of Achilles being smitten by the sword "*per utrumque latus geminato ictu transfigit*." (Dictys Cretensis, *cir.* A.D. 380). Tzetzes (in *Post Homericæ* 396) gives the same account. Indeed, comparing all this late Achillean literature, one can see the process of growth of the myth. Achilles, having abused the body of Hector by dragging him by the heel, must, in the interests of poetical justice, be put to death by injury to his heel; to render which possible the legend of invulnerability had to be invoked, and this determined the mode whereby he was rendered invulnerable, so as to leave the heel unprotected. The idea is essentially un-Homeric, for in *Il.* xxi. 166 Asteropæus wounds Achilles, "and the black blood gushed out." In spite of Prof. Hyrtl's protest, therefore, we must regard the name as arising from the Hector story, and, failing the discovery of an older source, probably having its original parentage in the passage in Vesalius.

A. M.

ANATOMICAL NOTES AND QUERIES.

47. Osteology and Syndesmology. Noteworthy papers:—

ALEZAIS on the diaphragmatic vertebra of Giebel, *Comptes Rendus, Soc. Biol. Paris*, 1898, p. 686.

ELDER, congenital absence of radius and thumb, *Tr. Med. Chir. Soc. Edinburgh*, xvii. p. 178.

PFITZNER, anomalies of the skeleton of the limbs, *Ergebn. d. Anat.*, vii.

BONNARME, the seventh cervical rib, Thesis, Paris, 1898.

BONNIFAY, cephalometric study of the growth of the head from infancy to maturity, Thesis, Lyons, 1897.

GRONNAUER, cervical rib, *Revue Médicale de la Suisse Romande*, 1898, 19.

REITTERER, ossification of the pisiform bone in man, rabbit, and dog, *C. R. Soc. Biol. Paris*, 1898, p. 435.

BRANCA, a trifurcation of Meckel's cartilage, *Journ. de l'Anat. et de la Phys.*, xxxiv. p. 757.

MIDDLETON, congenital absence of left ulna, *Glasgow Med. Journ.*, l. p. 244.

ROSENBERG, on a primitive form of vertebral column in man, *Morph. Jahrb.*, xxvii. p. 1. This is a very important paper.

FRIEBEN, congenital defect of the fibula, *Greifswald Dissertation*, 1899.

HANOTTE, pathology of oxycephaly, *Paris Thesis*, 1899.

GAUPP, metamerism of the skull, *Ergebnisse d. Anat. u. Entwickl.*, vii. p. 793.

WHITELEY and PEARSON, data for the problem of evolution in man. I. First study of the variability and correlation of the hand, *Proc. Roy. Soc.*, lxx., 1899, p. 126. A laborious study of the length of fingers.

COULLIAUX, anatomy, physiology, and pathology of the dental pulp, *Correspondenzbl. für Zahnärzte*, xxviii. p. 106.

MAGGI, suture-fontanellar ossicles in fossil human skulls, *Rendic. R. Instit. Lombard di Scienz. e Lett.*, xxxii. p. 465.

HOFFA, the human foot and its covering, Würzburg, Stahel, 1899, 16 pp.

PERRON, regressive character of the glenoid cavity among criminals, *Rev. Mens. di Pschiat. for. Antr. crim.*, i. p. 349, 1898.

AUVRAY, a double scaphoid in the hand, *Bull. Anat. Soc.*, Paris, 1898, p. 135.

HASSE, the teaching collection of the Breslau Anatomical Institute, *Archiv f. Anat. und Phys.*, 1899, p. 195.

MORSTIN, supernumerary lumbar and cervical ribs, *Bull. Soc. Anat.*, Paris, lxxiv. p. 401.

PAUL, the histological study of dentine, *Trans. Odontolog. Soc. of Great Britain*, March 1899, reprint.

SCHORSTEIN and CARPENTER, congenital absence of the clavicles, *Lancet*, p. 10 and p. 13.

DOLLO on the ligamentum teres, *Journ. Méd. de Bruxelles*, 1898, p. 4.

HOUSSAY on dental anomalies, *Rev. de la Société d'Anthrop. de Paris*, 1899, p. 37.

BÉDART on the presence of accessory scaphoid tubercles and the ossification of sesamoid bones in the foot, *Comptes Rendus de l'Association des Anatomistes*, 1899, p. 128.

RÉGNAULT on the intercondylar foramen of the humerus, *ibid.*, p. 112.

WILMART, three papers on joints, *Journ. Méd. de Bruxelles*, 1898, Nos. 43 and 46, 1899, No. 5.

KÜSS and PISSON, a process of the foetal lateral nasal cartilage which disappears in the adult, *Bibliog. Anat.*, vii. p. 53.

48. DELAYED UNION IN THE HIP-BONE in a left male hip-bone in which the acetabulum is perfectly developed and the epiphyses of the ischial tuberosity is almost completely united to the rest of the bone; the joint between the rami of the pubis and ischium is still unclosed. This, I think, is a very rare condition. I should like to get references to similar cases.

49. PERFORATION IN 12TH THORACIC VERTEBRA. — I have several specimens of this vertebra in which the bone is pierced on each side more or less vertically through the pedicle by a small straight or curved canal, which lies medial to the costal facet and on the ventral side of the base of the transverse process. I have never been fortunate enough to find it in a recent specimen, so cannot tell what passes through it, and shall be glad of any information on the subject.

50. EMARGINATE PATELLÆ.—In the Cambridge Collection there are at least twenty patellæ marked at the upper and outer margin by a more or less deep notch. I have not yet succeeded in finding it in a recent joint, and shall be much obliged for any information regarding its correlations.

51. Myology. Noteworthy papers:—

ABBOTT, abnormality of the sternum and diaphragm, *Tr. Path. Soc. Lond.*, xlix. p. 57.

FITZGERALD, anomalies of the orbital muscles, *B. M. Journal*, 1899, p. 699.

BESSER, mechanical action of the digital muscles, etc., *Lausanne Thesis*, 1898.

BOLK, homologies of thoracic and abdominal muscles, *Morph. Jahrb.*, xxvii. p. 317.

KIRSCHBAUM and DE KONING, absence of the sterno-costal part of the great pectoral and of the lesser pectoral, *Psychiatr. en neurol. Bladen*, iii. 222.

LUBOSCH, a coraco-antibrachialis muscle in man, *Morph. Jahrb.*, xxviii. p. 309.

FAISNEL, absence of sterno-cleido-mastoid and platysma, *Bull. Anat. Soc.*, Paris, lxxiv. p. 150.

BARBARIN, a double femoral origin of the popliteus muscle and a femoral head of soleus, *ibid.*, p. 174.

CANNIET, muscular anomalies: palmaris brevis, adductor magnus, abductor minimi digiti, orbicularis palpebrarum, and other facial muscles, *Bibliographie Anatomique*, vi. p. 62.

ARLOING and CHANTRE, effects of section of the nerves of the sphincter ani, *Comptes Rendus Acad. Soc.*, Paris, 1899, p. 700.

ANDERSON gives, in the *Monthly International Journal of Anat.*, xvi. p. 55, a short resumé of the Edinburgh discussion of the significance of anomalies.

JUVARA on the posterior annular ligament of the wrist and the synovial sheaths under it, *Archives des Sciences Médicales*, 1898, iii. p. 261.

52. FIBULAR ORIGIN OF ACCESSORIUS BILATERAL in a well-developed muscular male subject. On left side there was a strong fibrous loop extending from the posterior surface of the fibula, immediately above the origin of flexor longus hallucis to the posterior surface of the external malleolus. This loop arched over the origin of the flexor longus hallucis, and from it muscular fibres arose which converged to a tendon, which passed into the sole of the foot in the same sheath as the flexor longus hallucis. It was joined in the plantar region by the accessorius, and dividing, embraced the tendon of the flexor longus digitorum, to be finally inserted by two slips into the flexor longus hallucis. On the right side a similar muscle was present, though not so well marked. It was partly inserted into the inner side of accessorius and partly into an expansion joining the origin of flexor brevis digitorum.

FRANK BARNES,
Mason University College, Birmingham.

53. Vascular System. Noteworthy papers:—

WEBER on reticular formation in the right auricle and anomalous foramen ovale, *Bibliog. Anatomique*, vi. 17.

HOCHER, four valves in the pulmonary artery, *ibid.*, p. 113.

MOST, lymphatics of the larynx, *Anat. Anzeiger*, xv. 387.

CHUDZINSKY, muscular varieties in the races of man, *Mem. Soc. Anthropol. Paris*, xcvi. p. 226.

VON EBNER, on the walls of capillary veins in the spleen, *Anat. Anz.*, xv. p. 482.

FISCHER, vena azygos cutting off a lobe of the lung, *ibid.*, p. 476, and xvi. p. 91 (the latter article gives additional bibliographic references, but has not yet exhausted the literature of the subject).

LAUZZI, topography of the middle meningeal artery, *Boll. Soc. Nat. a Napoli*, xii. p. 128.

PITTS, transperitoneal ligature of the iliac arteries, *Lancet*, 1899, p. 142.

JAKOBSSON on the glandula coccygea, *Upsala läkereför. Förhandling*, iii., 1898, p. 234.

REMSTRÖM, embryological history of the septum auricularum, *ibid.*, p. 441.

DRESCHKE, persistence of the Ductus Arteriosus Botallii, *Wiener Klin. Wochens.*, xi., 1898, p. 1195.

GÉRARD, a similar case, *Bibliographie Anat.*, vi. p. 217.

FREYBERGER, patent interventricular septum and anomalous thoracic veins, *Tr. Path. Soc. London*, xlix. p. 35.

54. Visceral Anatomy. Noteworthy papers:—

BONNET, the mammary organs in the light of ontogeny and phylogeny *Ergebnisse d. Anat. u. Entwicklungsgesch.*, vii. 937.

RABL, skin, *ibid.*, p. 339.

REYNOLDS, hair studied for the medico-legal expert, *Tr. Amer. Micros. Soc.*, xix. p. 117.

CLAYPOLE, comparative histology of the digestive tract, *ibid.*, p. 83.

MEHNERT, clinical relations of œsophageal and aortic varieties, *Archiv. f. Klin. Chirurg.*, lviii. p. 183.

VON ZOEGE-MANTEUFFEL, axial rotation of the cæcum, *Verh. d. Deutsch. Ges. f. Chirurg.*, 1898, p. 546.

DIAMARE, morphology of the suprarenal body, *Anat. Anz.*, xv. p. 357.

MAUDE, case of pseudo-hermaphroditism, *Brit. Gynæcol. Jl.*, 1898.

SOLOWY, observations on pseudo-hermaphroditism, *Monats. f. Geburtsh.* ix. p. 210.

STICKER, histology of the mammary gland, *Archiv. f. Mikrosk. Anat. u. Entwickl.*, liv. p. 1.

WEX, histology of the pharyngeal tonsil, *Zeitsch. f. Ohrenheilk.*, xxxiv. p. 207.

DIXON, the form of the empty bladder, *Anat. Anz.*, xv. p. 405.

DONOGANY on the histology of the cartilaginous nasal septum, *Arch. f. Laryngol. und Rhinol.*, ix. p. 30.

ODDONO on appendices epiploicæ in the fœtus and infant, *Boll. Soc. Med.-Chir. de Pavia*, 1899, p. 3.

MURRAY, pathology of the thyroid gland, *Lancet*, March 11 and 18, 1899, reprint, and *Brit. Med. Journ.*, p. 577.

FLINT, reticulum of the adrenal, *Anat. Anz.*, xvi. p. 1.

STAHR, connexion of prostatic and vesical lymphatics, *ibid.*, p. 27.

HILDEBRAND, the presence of gastric glands in the œsophagus, *Münchener. Med. Wochenschrift*, xlv. No. 33.

BETTI on the relation of the larynx to the vertebral column in man, *Boll. di malattie dell' orecchio, della gola e del naso*, Florence, xvii., reprint.

WILLIAMS, two cases of accessory thyroid bodies at the base of the tongue, *Proc. Path. Soc. Philadelphia*, v., 1898, p. 28.

LUBLINSKI, doubling of the glosso-epiglottic ligament, *Monatschr. für Ohrenheilkunde*, xxxiii. p. 122.

VAUGHAN, persistence of branchial cleft, *Brit. Med. Journ.*, 1899, p. 148.

TUFFIER and JEANNE, study of the vermiform appendix and ileo-cæcal region based on 180 necropsies, *Revue de Gynécologie*, 1899, p. 235.

LANGLOIS and REHNS, suprarenal bodies during fœtal life, *Comptes Rendus, Soc. Biol. Paris*, vi., 1899, p. 146.

WRIGHT, a diverticulum from the bladder, *Lancet*, 1899, p. 763.

PRESTON, a patent urachus, *New York Med. Record*, xlix. p. 315.

AUDISTÈRE, a very long vermiform appendix without a mesenterium, in the inguinal canal, *Bull. Soc. Anat. Paris*, lxxiv. p. 144.

CHIEVITZ, topographical anatomy of the full term human fœtus, Copenhagen, 1899; an admirable monograph.

ROND, anomaly of the duodenum (its lower part lengthened, lying above the root of mesentery and visible for its whole length), *Bibliog. Anat.*, 1898, p. 209.

TALMA, the making of artificial anastomoses for the portal vein by producing adhesions between the great omentum, gall-bladder, and abdominal wall, *Berliner Klin. Wochens.*, 1898, No. 38.

KOCH, congenital anomalies of the position and arrangement of the human intestine, *Deutsche Zeitschr. für Chirurgie*, l. p. 1.

CHARPY on the anomalies of the pancreatic ducts, *Journ. de l'Anat. et de la Physiol.*, xxxiv. p. 720.

FLETCHER, uterus unicornis et vagina duplex, *Tr. Path. Soc. Lond.*, xlix. p. 190.

TÉMOIN, an accessory spleen, *Archives Provinciales de Chirurgie*, 1878, p. 622.

FRAISSE, vesical topography in the female, *La Semaine Gynécologique*, 1898, No. 10.

FREUND, on Douglas' cul-de-sac, *Bull. Soc. Anthropol. de Paris*, 1898, p. 589.

COSMETTATOS on the development of the lacrymal passages, *Paris Dissertation*, 1898.

E. VON BENEDEN, an archenteric canal in man, *Anat. Anzeiger*, xv. p. 249.

HAPPHEL on the function of some of the laryngeal muscles, *Klinische Jahrb.*, 1898.

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57. Professor Arthur Thomson is publishing in *Knowledge*, vol. xxii., a series of popular articles on the physical data of Anthropology: he has in the articles hitherto issued dealt with colour, hair—clothing, stature, and limb-length.

A. M.

Notices of New Books.

Traumatic Separation of the Epiphyses. By JOHN POLAND,
F.R.C.S. Eng. Smith, Elder & Co., London, 1898.

Skiagraphic Atlas. By JOHN POLAND, F.R.C.S.

No study of the bones of the human skeleton is complete without a thorough knowledge of the anatomy of the epiphyses. In an examination confined to the macerated adult skeleton there is undoubtedly a danger of the student overlooking both the anatomical and surgical importance of the epiphysial cartilages. In the investigation of injuries in the neighbourhood of the joints in early life, the presence of these structures must not be forgotten. The large volume now before us gives some indication of the important place which the epiphyses occupy in surgery, and it cannot be gainsaid that injuries in their vicinity form some of the most difficult cases which the surgeon may be called upon to diagnose and treat.

Mr Poland has presented to the profession a very complete account of this subject, and his admirable work will prove of great value as a book of reference. The etiology and mechanism of these injuries are fully entered into, and he discusses at length both prognosis and treatment. The normal anatomy of the ends of the long bones is presented in very considerable detail, and this, as well as many of the common forms of injury, is profusely illustrated, a section of the work which reflects great credit upon both author and publishers. The author has called into requisition for this purpose the new skiagraphy, which undoubtedly lends itself very effectively to the portrayal both of the normal conditions and of those pathological lesions produced by traumatism. In connection with this, it may be noted here that Mr Poland has republished in a separate form a small skiagraphic atlas, showing the development of the bones of the wrist and hand. The author has evidently taken great pains to collect and analyse the somewhat extensive literature which deals with this subject, and the completeness with which this has been done will certainly enhance the value of the volume.

We turn with special interest to the chapters upon injuries about the elbow, as it is in this region that deformity may be followed by such serious consequences to the patient with regard to the future usefulness of the upper extremity. Rapid and firm union results, but even in the simplest cases it is advisable to make a guarded statement concerning the future usefulness of the limb. The ultimate prognosis, however, is, as a rule, good, a result which is dependent not only upon careful treatment, but also upon the correctness of the diagnosis. For a proper appreciation of such points as these, and for the purpose of acquiring much valuable information in this branch of surgery, we recommend this volume to every practical surgeon.

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PROCEEDINGS OF THE
ANATOMICAL SOCIETY OF GREAT BRITAIN
AND IRELAND.

NOVEMBER 1898.

THE Annual General Meeting of the Society was held at King's College, on Friday, November 25th, 1898, at 4 P.M. The President, Professor A. MACALISTER, F.R.S., was in the chair, and seventeen members and twenty-one visitors were present.

The HON. TREASURER, in presenting his Annual Report, showing a balance in hand of £57, 5s. 2d., said that the financial feature of the past year had been the expenditure on publications of the sum of £77, as against an average of £40 for the previous seven years. The cost of printing had exceeded that of any previous year, and the cost of illustration that of any two previous years up to 1897. The expenditure on publications of the two years 1897-98 amounted in all to £142, the large increase over previous years being mainly due to the cost of publication of papers read at the Summer Meeting of 1897; and, speaking for himself, he remarked that, since that had given the Society papers of such great morphological value as those by Drs Elliot Smith and Disse, he considered they had cause to be content with the bargain.

Commenting upon the income, he said that although that of the year had fallen short of the actual expenditure by over £20, the sum received in current subscriptions had, nevertheless, exceeded the average of all previous years, and that the receipt of subscriptions in arrear averaged little more than half that of the past, as the result of their having been nearly all recovered up to 1897.

He reported 9 resignations during the year, and a present roll

of 143 members, and drew the conclusion that since the subscriptions for the coming year, if paid to date, should thus realise a sum of £75, the financial position of the Society, while justifying the continuance of the present rate of expenditure, invited the consideration of some new sphere of usefulness.

The following officers for the ensuing year were then elected :—
President—A. Macalister, M.D., F.R.S. *Vice-Presidents*—A. Birmingham, M.B.; C. B. Lockwood; B. C. A. Windle, M.D., B.Sc. *Treasurer*—G. B. Howes, LL.D., F.R.S. *Secretaries*—A. Keith, M.D. (England); J. Musgrove, M.D. (Scotland); W. S. Houghton, M.B. (Ireland). *Council*—J. Black, M.B.; Stanley Boyd, B.S.; T. Bryce, M.D.; D. J. Cunningham, M.D., F.R.S.; A. F. Dixon, M.B.; E. Fawcett, M.B.; H. Gadow, F.R.S.; Robert Howden, M.B.; A. W. Hughes, M.D.; J. Yule Mackay, M.D.; G. H. Makins; F. G. Parsons; A. M. Paterson, M.D.; Arthur Robinson, M.D.; Barclay-Smith, M.D.; J. Symington, M.D.; G. D. Thane; Arthur Thomson, M.B.; Sir Wm. Turner, F.R.S.; A. H. Young, M.B.

A vote of thanks to the retiring Vice-President and Secretary was passed.

The following new members were elected :—T. R. ARMOUR, M.B., Senior Demonstrator of Anatomy, University College, Liverpool, proposed by A. M. Paterson, W. Turner, F. G. Parsons. B. G. A. MOYNIHAN, M.S., F.R.C.S., Hon. Demonstrator of Anatomy, Yorkshire College, Leeds, proposed by T. Wardrop Griffith, A. Macalister, A. Hughes. CECIL C. LEAF, M.B., F.R.C.S., Demonstrator of Anatomy, London Hospital Medical College, proposed by A. Keith, A. Macalister, A. Robinson. J. P. MUDGE, A.R.C.S., Demonstrator of Biology, London Hospital Medical College, proposed by G. B. Howes, A. Keith, F. G. Parsons. W. G. RIDWOOD, D.Sc., proposed by G. B. Howes, E. Lane, F. G. Parsons.

Mr F. G. PARSONS then suggested that it was desirable that, if possible, a closer connection should exist between the Anatomical Society and the *Journal of Anatomy and Physiology*. He called attention to the fact that the *Journal* was the recognised and only organ in the English language on Human and Vertebrate Anatomy, and submitted that it would be to the interest of all if more members of the Society could be induced to take it in. He said that he had the authority of the proprietors of the *Journal* in stating that, if

sufficient members would take it up, the *Journal* could be supplied to members of the Society for 25s. per annum, this sum to include their membership subscription. He asked permission for the Secretary to send out a circular, in order to see how much support to this proposal would be forthcoming. The question was debated at some length, and it was finally decided to refer it back to the Committee of Management for further consideration, with permission, if it were thought advisable, to send out the suggested circular.

Peculiarities of the Fœtal Vertebral Column.

Prof. PATERSON and Dr LOVEGROVE exhibited the vertebral columns of three stillborn full-time fœtuses, from a series of 97 macerated fœtal skeletons of all ages, 48 of which were of 9 months. The three spines presented were the only ones which showed marked peculiarities, variations in the number of ribs excepted.

(1) In one case the abnormality consisted in the absence of the posterior circle of the atlas on the right side. The occipital bone was normal.

(2) The second case presented an instance of irregular fusion of the bodies of certain vertebræ (fig. 1). The neural arches and ribs were normal. The total number of vertebral bodies represented was 29, no coccygeal centres having appeared. The number of ribs was 12 on each side.



FIG. 1.

Three sets of adjacent vertebral bodies were peculiar:—(a) The 6th thoracic vertebral body was large and slightly bilobed, and the 7th was merely half a body intercalated between parts of the 6th and 8th. (b) The 4th and 5th lumbar and the 1st sacral bodies were fused together, the line of junction being well marked in the case of the 5th lumbar and 1st sacral, but merely indicated by lateral notches in the case of the 4th and 5th lumbar bodies. (c) The 4th and 5th sacral bodies were also fused together. The basi-occipital bone of the skull had a deep notch in it on the left side.

(3) In the third case the spine consisted of 30 vertebræ, of which 26 were præsacral. The neural arches in the cervical region presented the most striking abnormality (fig. 3, a, b, c). The atlas and axis were normal. The left half of the third and the right half of the fourth neural arches were deficient, so that the articulation of the neural arches occurred between the right third and the left fourth arches. The neural arches on the left side belonging to the fifth and sixth vertebræ were fused posteriorly to form a single lamina, which articulated with the lamina of the fifth vertebra on the right side.

The ribs in this case were markedly asymmetrical. On the right side there were 13 thoracic ribs, and a minute ossification for the anterior lamella of the seventh cervical vertebra. On the left side



FIG. 2.

there was a well-marked cervical rib and 12 thoracic ribs, the first of which was intermediate in size and characters between the first and second ribs of the right side. The sixth and seventh ribs on the left

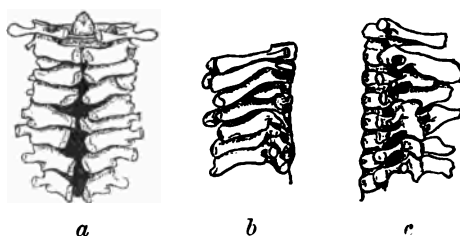


FIG. 3.—a, dorsal view; b, right lateral view; c, left lateral view.

side were fused together by bony union near their vertebral ends for a short distance (fig. 2).

The sternum in this case was normal, and presented costal cartilages for seven ribs on each side.

Fused Atlas and Occipital Bone.

Professor HUGHES showed a *dissection of Muscles and Nerves* in the sub-occipital region in a case of fused atlas and occipital.

The atlas consisted of two distinct parts, the right half being free and movable, while the left half was almost completely fused to the occipital bone.

The muscles and nerves on the *right* side were normal in their arrangement. On the *left* side some modifications were noticed.

The sub-occipital nerve emerged in two divisions through two distinct foramina, between the fused half of the atlas and occipital, the anterior division passing to join the anterior division of the second nerve. The posterior division was very small, and emerged through the posterior foramen, and having supplied the rectus capitis posticus major, joined a large branch of the posterior division of the second

cervical nerve, from which twigs were supplied to the superior and inferior oblique muscles, and to the complexus.

The left superior oblique muscle consisted of two parts, a small deep portion, almost ligamentous in character, being attached to the transverse process of the fused atlas, and a large superficial portion which extended from the occipital bone to the transverse process of the axis-vertebra.

The rectus posticus minor was absent on the left side.

The vertebral artery ascended vertically into the skull on the left side through a foramen in the fused atlas.

Abnormal Kidney.

Mr H. W. HARDING, introduced by Dr Arthur Robinson, said that the specimen shown was removed after death from a patient who had been in the London County Lunatic Asylum, Hanwell, twenty-six years.

The right kidney was found in the normal position, so also was the left suprarenal body, while the left kidney was found on the brim of the pelvis, with its upper end about one inch below the bifurcation of aorta. It was lying parallel to and over the left iliac vessels, the bifurcation of the common iliac being concealed by it. The vascular supply was as follows:—There were two arteries, one running from the *anterior-front surface* of the aorta about one-third of an inch above level of bifurcation, whilst the other rose posteriorly from the bifurcation itself in the situation from which the median sacral arises. This latter vessel appears to be represented by a small branch from this posterior renal artery about one inch from its origin.

As regards the venous supply, the renal vein, emerging from the outer border of the kidney, ran upwards and slightly inwards, external to the left common iliac artery: one inch above the kidney it was joined by the left common iliac vein, the resulting vein then running upwards along the left side of the aorta as far as the interval between the second and third pair of lumbar arteries, where it passes behind the aorta and enters the vena cava. This receives lumbar veins of that side.

There is an obliterated vein running between the left common iliac and inferior vena cava in the situation of the normal junction.

Another and much smaller renal vein runs from the inner border of the kidney across the right common iliac artery and enters the lower part of the inferior vena cava.

The following points are of interest:—

1. The kidney retains the situation in which it is developed—first and second (now) sacral vertebræ.
2. The absence of any adhesions or of any contraction of the ureters suggesting a cause for its abnormal situation.
3. Ureter emerges from its anterior aspect.
4. Its arterial supply from the aorta and median sacral, both

vessels coming from the aorta low down, near the situation of the kidney.

5. The presence of the two veins in connection with remains of the cardinal veins of either side.

6. The upper transverse anastomosis between the right and left cardinal veins is not at the level of the right renal vein, but below it; and it is also posterior to the aorta.

Prof. B. C. A. WINDLE read a note on *Epignathus*, which is published in full in the present (January) number of the *Journal of Anatomy*.

Prof. ARTHUR THOMSON read a paper on the *Sexual Differences of the Fœtal Pelvis*, which will be published *in extenso* in the April number of the *Journal*.

Dr PETER THOMSON read a paper on the *Levator ani, or Ischio-anal Muscle of Ungulates*. This will be printed *in extenso* in the April number of the *Journal of Anatomy*.

PROCEEDINGS OF THE
ASSOCIATION OF AMERICAN
ANATOMISTS.

THE Eleventh Annual Session was held in New York city, 28th to 30th December, in conjunction with the "Naturalists" and other affiliated Societies. Most of the meetings were held at the Medical Department of Columbia University. Forty-one members attended and 20 new members joined, making a total membership of 141, of whom 10 are honorary. The localities and names of the new members are as follows:—

From Ann Arbor, Professor J. P. McMURRICH, University of Michigan; from Baltimore, Professors F. P. MALL and L. F. BARKER, and Associate R. G. HARRISON, of the Johns Hopkins University; from Buffalo, Dr N. S. RUSSELL, Assistant in Anatomy, University of Buffalo; from Ithaca, Dr L. COVILLE, Lecturer and Demonstrator in Anatomy, Cornell University Medical College; from Montreal, Dr J. G. MACCARTHY, Senior Demonstrator of Anatomy, M'Gill University; from New York city, Professor J. D. ERDMANN, of Bellevue Medical College; Dr EVELYN GARRIGUES, Assistant Demonstrator of Anatomy, Women's Medical College; Dr ALES HRDLICKA, Associate in Anthropology, Pathological Institute of N.Y. Hospitals; and the following Assistant Demonstrators of Anatomy in Columbia University,—Doctors G. E. BREWER, C. CARMALT, H. D. COLLINS, G. W. CRAIG, W. MARTIN, W. H. ROCKWELL, and A. S. VOSBURGH; from Philadelphia, Professor J. C. HEISLER, of the Medico-Chirurgical College; from Savannah, Dr E. R. CORSON; from Washington, D.C., Dr C. I. WEST, Demonstrator and Lecturer in Topographical Anatomy, Howard University.

The address of the President, Dr BURT G. WILDER, discussed "Misapprehensions as to the Simplified Nomenclature." The speaker urged especially a fuller recognition of what had been done by the

English anatomists Barclay, Owen, Pye-Smith, and T. Jeffrey Parker, and hoped the nomenclature of the future would be called the "Anglo-American."

The Association voted that abstracts of papers be required in advance, and that brief abstracts be included in the programme; that the time for reading papers be limited to thirty minutes; that the Secretary-Treasurer be allowed his railroad fare and 10 dollars towards his hotel expenses at each meeting. The Association also accepted the propositions of the Editors of the (English) *Journal of Anatomy and Physiology* as to making that Journal the official organ of the Association, and nominated Professor GEORGE S. HUNTINGTON as the American Editor. The details of the arrangement will be given in a circular to be issued by the Secretary of the Association. Dr E. W. HOLMES, of Philadelphia, was elected member of the Executive Committee, and the President was authorised to fill the vacancy in the Committee on Anatomical Nomenclature caused by the resignation of Dr DWIGHT.¹

The subject assigned for discussion, "The Teaching of Anatomy in our Medical Schools," was opened by Dr HOLMES, "The defects of our present methods," and further considered under ten divisions, viz., (1) Preparatory education; (2) The value and place of general biology and comparative anatomy; (3) Histology and embryology in the medical course; (4) The relative value of didactic methods; (5) Practical anatomy, and how to teach it; (6) The order of topics; (7) The correlation of structure and function in teaching; (8) The use of charts and blackboards; (9) The qualifications requisite for a teacher of anatomy; (10) The desirability of terminologic consistency;—by Dr GERRISH (4, 6, and 8); by Dr HUNTINGTON (2, 3, 5, and 6); and Dr WILDER (10). In view of the extent and importance of the subject, it was suggested that at future meetings a smaller number of divisions be more fully considered.

The following papers were read and discussed. All were illustrated by specimens, and charts or photographs, and several by lantern-slides or enlarged photographic projections:—

J. A. BLAKE:—"The roof and lateral recesses of the fourth ventricle, considered morphologically and embryologically."

G. E. BREWER:—"Preliminary report on the surgical relations of the duodenal orifice of the common bile-duct."

¹ Dr E. C. Spitzka, of New York city, has since been selected.

E. R. CORSON:—"An X-ray study of the normal movements of the carpal bones and wrist."

F. DEXTER:—"Morphology of the digestive tract of the cat."

T. DWIGHT:—"The origin of numerical variations of the vertebræ," and "The living model showing the platysma in contraction."

S. H. GAGE:—"Further notes on the relation of the ureters and great veins."

I. S. HAYNES:—"An explanation of a new method of cutting gross sections of the cadaver, with demonstration of the technique."

ALAN HRDLICKA:—"The normal human tibia."

G. S. HUNTINGTON:—"Morphology and phylogeny of the vertebrate ileo-colic junction," "Visceral and vascular variations in human anatomy," and "The sternalis muscle."

W. MARTIN:—"The cæcum and appendix in one hundred subjects."

J. J. MACCARTHY:—"The internal structure of the hippocampus."

B. B. STROUD:—"Note on the staining of isolated nerve-cells," and "Preliminary account of the degenerations in the central nervous system of frogs deprived of the cerebrum."

B. G. WILDER:—"Some current misapprehensions as to the objects of the Cornell Collection of brains."

For lack of time, there were read by title only Dr WILDER's paper, "Further tabulation and interpretation of the paroccipital fissure (occipital division of the intraparietal complex)"; three papers by Dr HUNTINGTON, "The genito-urinary system of the American pit-viper," "Contribution to the anatomy of the reptilian vascular system," and "Cerebral fissures and visceral anatomy of the Eskimo from Smith's Sound"; and Dr HAYNES' discussion of teaching.

At its closing session, 30th December, the Association adopted without dissent the Report of the Committee on Anatomical Nomenclature, presented by the majority (GERRISH, HUNTINGTON, and WILDER). It comprises four divisions, viz.—

A. Brief statement of reasons for preferring certain terms (about fifty in number) already adopted by the Association.

B. Recommendation of *mesocelia* as a name for the cavity of the mesencephalon, with reasons therefor.

C. Recommendation of 181 names of bones (120) and muscles (61) identical with those in the B.N.A. (Basel Nomina Anatomica).¹

D. Recommendation of 17 names of bones and muscles differing from those of the B.N.A.

¹ This portion was already written last year, but was not printed on account of the supposed necessity of having the last Report ready for distribution at a certain date. The numbers in parentheses correspond with the serial numbers in that Report (*Proceedings of the Tenth Annual Session*, pp. 9, 47-53). Some of these terms are more fully discussed by the Secretary of the Committee in "Neural Terms, International and National," *Journal of Comparative Neurology*, vi., December 1896, pp. 216-352, including seven tables. Parts vii.-ix. have also been reprinted under the title "Table of Neural Terms, with Comments and Bibliography."

REPORT.

"A. *Brief statement of reasons for preferring certain neural terms included in the report adopted at the last meeting of the Association.*"

Alba (1); cinerea (2); gelatinosa (3); reticularis alba (77); caudatum (89); pallidum (108); albicans (123); entocinea (143); intercalatum (144); and arachnoidea (208), are neuter or feminine adjectives used as substantives, and comparable in that respect with cases already discussed, viz., callosum (§ 13) and dura (§ 15); special points connected with them may be considered hereafter.

Limen (6); caput (90); cauda (91); fimbria (94); splenium (96); genu (97); rostrum (98); corona (110); tuber (124); valvula (148); frenulum (149); lingula (154); arbor (166); calamus (173); ligula (176); pyramis (181); conus (189); filum (190); cisternæ (219); glomus (277); circulus (231); torcular (251), are more or less closely comparable with calcar, chiasma, tentorium, and falx (§§ 9-12) in that, even when not absolute idionyms, their signification would be determined by the context, or could be indicated by a word that need not be repeated.

In replacing "substantia corticalis" by cortex (105); "nucleus lentiformis" by lenticula (107); "corpus geniculatum" by geniculum (116, 117); "lamina terminalis" by terma (128); "corpus trapezoideum" by trapezium (165); "nucleus emboliformis" and "n. globosus" by embolus and globulus (170, 171); "corpus restiforme" by restis (184); "formatio reticularis" by reticula (206), we simply replace phrases, including adjectives that suggest resemblance to objects (simile names), by the substantive names of the objects themselves. In so doing we follow the actual example of the B.N.A. in preferring (§ 6) oliva to "corpus olivare," clava to "processus clavatus," vermis to "processus vermiformis," and pyramis to "corpus pyramidale." Indeed, the logical extension of the system embodied in the retention of "corpus restiforme," when restis is available, would burden anatomy with gyrus insuliformis, corpus pontiforme, and corpus hippocampoides, none of which, fortunately, has materialised.

Endyma (4).—As well stated by Hyrtl (*Onomatologia*, p. 200) the initial syllable of "ependyma" is quite superfluous. If, on the other hand, the qualifying genitive "ventriculi" is required, as in the B.N.A., why not "cerebri" also, in order to secure absolute explicitness? As a matter of fact, both endyma and "ependyma" are idionyms, and the former is as much better as it is shorter.

Habena (120), vallis (153), and acervus (218) are preferred to the diminutives "habenula," "vallecula," and "acervulus," because they are shorter; "acervulus," moreover, is a modern coinage.

Gyrus subcalcarinus (61) and gyrus subcollateralis (60).—These terms are recommended in place of "gyrus lingualis" and "gyrus fusiformis" respectively. The difficulty of applying the latter is

well known; indeed, so vague are the resemblances implied in them that certainty can hardly be ensured without resort to the rather puerile mnemonic device of associating the letter *n* in calcarinus and lingualis. But since fissura calcarina and fissura collateralis are now almost universally employed, and no new words have to be introduced, there seem to us to be several advantages and no disadvantages in designating the gyri just ventrad of the two fissures respectively by terms indicating their relative positions.

Gyrus subfrontalis (46).—In the B.N.A. was adopted "gyrus frontalis inferior," to the exclusion of the common synonyms "convolutio Brocæ" and "gyrus frontalis tertius."¹ The question is therefore narrowed down to the relative merits of "gyrus frontalis inferior," as adopted in the B.N.A., and gyrus subfrontalis as preferred by us; and since this is a type of a large number of cases of difference between the two lists, it will be presented in some detail.

The two terms agree in being both distinctly locative names. The location of a part is a general and comprehensive attribute, and, as remarked by Owen, "signifies its totality without calling prominently to mind any one particular quality, which is apt thereby to be deemed, undeservedly, more essential than the rest." Locative names form two natural groups, Prepositional and Adjectival. Prepositional locatives.—With these the qualifying prefix, a preposition or adverb, indicates the location of a part relatively to some other part, more important, more easily recognised, or previously designated. Præcuneus designates a cortical area just "in front of" the cuneus; subcalcarinus and subcollateralis are prepositional locatives. Adjectival locatives.—These indicate either the location of a part within some general region, or its membership of a series. Vertebra thoracalis designates a spinal segment in the thorax. Commissura anterior, cm. media, and cm. posterior distinguish members of a series. Subfrontalis is an adjectival locative, and the preposition *sub* is employed as a prefix in the sense of inferior or lower; it is also a true mononymic adjective, and not a quasimononym like the hyphenated "infero-frontalis" sometimes employed.

B. *Mesocœlia* (English *mesocœle* or *mesocœle*).—This single word is recommended as a name for the entire cavity of the mesencephalon, the region including the crura and the quadrigeminum.

The following considerations apply to the general use of *cœlia* (English *cœle* or *cele*) in place of *ventriculus*.

(1) Its Greek origin renders it compoundable regularly and

¹ Both these names were rejected by the Secretary of this Committee in 1885 ("On two little known cerebral fissures, with suggestions as to fissural and gyral names," *Amer. Neurol. Trans. ; Jour. Nerv. and Mental Disease*, xii.; abst. in *Neurology Centralblatt*, Dec. 15, 1885), the former as an eponym, as including the needlessly long word *convolutio*, and the latter as a trionym, and because the enumeration of the three concentric frontal arches might quite as naturally begin with the "inferior" as with the "superior"; indeed, this was done by Meynert (*Psychiatry*, fig. 9); likewise by Leuret in the analogous case of the arches about the Sylvian fissure of carnivora.

euphoniously with the characteristic prefixes already employed in the segmental names, *e.g.*, mesencephalon, etc. (2) These compounds are mononyms, and therefore capable of inflection (*e.g.* mesocœliæ), derivation (*e.g.* mesocœlianæ), and adoption into other languages without material change; *e.g.*, English, mesocele; French, mesocœlie; German, mesokölie; Italian, mesocelia. (3) The various national paronyms thus formed are likewise capable of derivation, *e.g.* mesocœlian.

(4) There is classic authority for the use of cœlia in the sense of encephalic cavity. In the lexicon of Liddell and Scott, *κοιλία ἐγκεφάλου* is quoted as in good and regular standing among Greek medical writers. According to Burdach ("von Baue und Leben des Gehirns," 1819-22, ii. 301, 378, 380), Galen designated the "fourth ventricle" as *κοιλία ὀπισθοῦ ἐγκεφάλου, τετάρτη κοιλία*, and *ὀπισθία κοιλία* (De usu partium, lib. viii., cxii. p. 170); the "third ventricle" as *μέση, τρίτη κοιλία* (*idem*, ix., iii. 172); and the "lateral ventricles" as *προσθία κοιλία* (De odoratus instrumento, ii. 110). Cœlia is then certainly not "new."¹ (5) These ancient usages are assumed to be familiar to most anatomists, who therefore should recognise the compounds with little or no hesitation. (6) The compounds are so euphonious and so obviously correlated with the segmental names as to be learned and remembered easily, even by general students and by such as may not have had a classical training.

(7) In recent times cœlia has been independently proposed by two anatomists, teachers as well as investigators.² (8) It has been adopted more or less completely by four of the older American neurologists—C. K. Mills ('97), Henry F. Osborn ('82, '84, '88), E. C. Spitzka ('81, '84), and R. Ramsay Wright ('84, '85); and unreservedly by eight of the younger—W. Browning, T. E. Clark, P. A. Tish, Mrs S. P. Gage, O. D. Humphrey, B. F. Kingsbury, T. B. Stowell, and F. B. Stroud.

(9) Cœlia and its compounds are idionyms, *i.e.*, used in no other sense in normal vertebrate anatomy; hence, unlike ventriculus and its compounds, they are free of ambiguity. This argument is stated last, because it seems to the Committee of comparatively slight importance. Theoretically, of course, ventriculus (encephali) might be mistaken for ventriculus (cardiæ s. cordis). Practically, however, the context would almost infallibly obviate misapprehension. Hence the absolute unambiguity of cœlia and its compounds would not in itself justify its replacement of ventriculus. It would be a *causa vera*, but hardly a *causa sufficiens*.

¹ Dr Achilles Rose, of New York city, informs the Secretary of the Committee that in the modern Greek treatise on anatomy by Παπαϊωάννου (Athens, 1888-1890, 3 vols.), the encephalic cavities are designated by *αἱ πλάγναι κοιλίαι; τρίτη ἢ μέση κοιλία τετάρτη κοιλία*.

² The Secretary of this Committee, March 1881, and Prof. T. Jeffrey Parker, of Otago, New Zealand, Aug. 1882: in addition to the three publications enumerated in the bibliography of "Neural Terms," there should be named his two papers on *Apteryx* (*Philos. Trans.*, 1891 and 1892), and Parker and Haswell's *Zoology*, 1897.

The special arguments for the adoption of mesocœlia in advance of the other cœlian compounds are four:

(1) There is substantial agreement among anatomists in recognising a definitive encephalic segment under the title mesencephalon; this cannot yet be said of the other regions.

(2) The cavity of this segment has no common ventricular designation like "quartus," "tertius," and "lateralis."

(3) The terms *ventriculus mesencephali* or *v. mesencephalicus* (English, mesencephalic ventricle or cavity) are seldom used, and are somewhat clumsy. Even less convenient are the phrases "*aqueductus cerebri Sylvii*" and "*iter a tertio ad quartum ventriculum*."

(4) The abbreviations *iter* and *aqueduct*, while sufficiently descriptive of the adult conditions in man and other mammals, are quite inappropriate to the "vast and spacious cavity" of the embryonic mesencephalon, and to the lateral extensions in frogs, reptiles, and birds.

C. Names of bones and muscles identical with those in the B.N.A.

In the B.N.A. the special names under osteologia and myologia number about 885 and 350 respectively, total about 1235. Of these the Committee recommend the adoption of 181 (120 of bones, 61 of muscles).

In the 17 cases of difference from the B.N.A. the Committee believe the terms preferred by them will, upon due reflection, commend themselves to the large majority of English-speaking anatomists.

Columna vertebralis.	Vertebræ cervicales.
Vertebræ thoracales.	Vertebræ lumbales.
Vertebræ sacrales.	Foramen intervertebrale.
Atlas.	Processus spinosus.
Vertebra prominens.	Promontorium.
Thorax.	Costæ.
Sternum.	Cavum thoracis.
Ossa cranii.	Os occipitale.
Condylus occipitalis.	
Os sphenoidale.	Sinus sphenoidalis.
Foramen opticum.	Foramen rotundum.
Foramen ovale.	Foramen spinosum.
Processus pterygoideus.	Fossa scaphoidea.
Canalis pterygoideus (Vidii).	Os temporale.
Pars mastoidea.	Processus mastoideus.
Foramen mastoideum.	Pars petrosa (Pyramis).
Canalis facialis (Fallopil).	Aquæductus vestibuli.
Incisura jugularis.	Fossa jugularis.
Processus styloideus.	Canalis caroticus.
Pars tympanica.	Squama temporalis.
Processus zygomaticus.	Fossa mandibularis.
Os parietale.	Os frontale.
Sinus frontalis.	Os ethmoidale.

Lamina cribrosa.	Crista galli.
Processus uncinatus.	Os lacrimale.
Os nasale.	Vomer.
Maxilla.	Sinus maxillaris.
Tuber maxillare.	Processus alveolaris.
Os palatinum.	Mandibula.
Ramus mandibulæ.	Angulus mandibulæ.
Processus condyloideus.	Processus coronoideus.
Os hyoideum.	Cranium.
Calvaria.	Diploe.
Vertex.	Frons.
Occiput.	Palatum durum.
Orbita.	Sutura coronalis.
Sutura sagittalis.	Sutura lambdoidea.
Scapula.	Spina scapulæ.
Acromion.	Incisura scapulæ.
Processus coracoideus.	Clavicula.
Extremitas sternalis.	Extremitas acromialis.
Humerus.	Caput humeri.
Fossa olecrani.	Fossa coronoidea.
Fossa radialis.	Radius.
Processus styloideus.	Ulna.
Olecranon.	Processus coronoideus.
Processus styloideus.	Carpus.
Metacarpus.	Phalanges digitorum manus.
Ossa sesamoidea.	Os coxæ.
Foramen obturatum.	Acetabulum.
Fossa acetabuli.	Incisura acetabuli.
Fossa iliaca.	Os pubis.
Eminentia iliopectinea.	Pelvis.
Symphysis ossium pubis.	Arcus pubis.
Femur.	Caput femoris.
Trochanter major.	Trochanter minor.
Fossa trochanterica.	Linea aspera.
Tibia.	Tibula.
Patella.	Tarsus.
Metatarsus.	Phalanges digitorum pedis.
Ossa sesamoidea.	
Musculus trapezius.	M. levator scapulæ.
M. iliocostalis.	M. longissimus.
M. masseter.	M. temporalis.
M. digastricus.	M. stylohyoideus.
M. mylohyoideus.	M. geniohyoideus.
M. platysma.	M. sternohyoideus.
M. omohyoideus.	M. sternothyroideus. ¹
M. thyrohyoideus. ¹	

¹ In the B.N.A. these names are sternothyreoideus and thyreochoideus. While not questioning the etymologic accuracy of these forms, the Committee believe that, as with chorioideus *versus* choroideus, the extra vowels and syllable are needless, and not likely to be pronounced even if retained.

M. subclavius.	M. diaphragma.
M. rectus abdominis.	M. pyramidalis.
M. cremaster.	Ligamentum inguinale (Poupart).
M. deltoideus.	M. brachialis.
M. anconæus.	M. pronator teres.
M. flexor pollicis longus.	M. pronator quadratus.
M. brachioradialis (supinator longus).	
M. extensor digitorum communis.	M. supinator.
Musculi lumbricales.	Musculi interossei dorsales.
Musculus iliacus.	M. tensor fasciæ latæ.
M. quadratus femoris.	M. sartorius.
M. quadriceps femoris.	M. rectus femoris.
M. vastus intermedius.	M. articularis genu.
M. biceps femoris.	M. semitendinosus.
M. semimembranosus.	M. extensor digitorum longus.
M. peronæus tertius.	M. peronæus longus.
M. peronæus brevis.	M. gastrocnemius.
M. soleus.	M. tendo calcaneus (Achillis).
M. popliteus.	M. flexor digitorum longus.
M. flexor hallucis longus.	M. extensor digitorum brevis.
M. abductor hallucis.	M. adductor hallucis.
M. flexor digitorum brevis.	Musculi lumbricales.
Musculi interossei dorsales.	Musculi interossei plantares.
Canalis adductorius (Hunteri).	

D. *Names of bones and muscles unlike those in the B.N.A.*

Axis *for* epistropheus ;
 Sacrum *for* os sacrum ;
 Coccyx *for* os coccygis ;
 Foramen magnum *for* foramen occipitale magnum ;
 Os malæ ¹ *for* os zygomaticum ;
 Zygoma *for* arcus zygomaticus ;
 Ossa membri thoracalis *for* ossa extremitatis superioris ;
 Ossa membri pelvici *for* ossa extremitatis inferioris ;
 Ilium *for* os ilium ;
 Ischium *for* os ischii ;
 Tuber ischii *for* tuber ischiadicum ;
 Spina ischii *for* spina ischiadica ;
 Musculus latissimus *for* latissimus dorsi ;
 M. sternomastoideus *for* sternocleidomastoideus ;
 M. biceps *for* biceps brachii ;
 M. triceps *for* triceps brachii ;
 M. accessorius *for* quadratus plantæ.

D. S. LAMB, *Secretary.*

¹ As in John Bell's "Engravings," etc. First American from second London edition. Philadelphia, 1817, part i., plate i. fig. 1, p. 33.

PROCEEDINGS OF THE
ANATOMICAL SOCIETY OF GREAT BRITAIN
AND IRELAND.

FEBRUARY 1899.

AN Ordinary Meeting of the Society was held on Friday, February 10th, at 4.30 P.M., at the Medical School of St Bartholomew's Hospital. Professor ALEXANDER MACALISTER, the President, was in the chair. Seventeen members and three visitors were present.

The minutes of last meeting were read and confirmed.

The following gentlemen were elected members of the Society:—
H. K. ANDERSON, M.D., Demonstrator of Physiology, University of Cambridge, proposed by A. Macalister, E. Barclay Smith, G. Elliot Smith. G. F. ROGERS, M.D., Assistant Demonstrator of Anatomy, University of Cambridge, proposed by A. Macalister, E. Barclay Smith, W. Bishop Harman. DOUGLAS CRAWFORD, F.R.C.S., Demonstrator of Anatomy, University College, Liverpool, proposed by A. M. Paterson, E. Barclay Smith, F. G. Parsons. W. L. H. DUCKWORTH, M.A., Lecturer on Anthropology, and Fellow of Jesus College, Cambridge, proposed by A. Macalister, E. Barclay Smith, G. Elliot Smith. FRANK BARNES, M.R.C.S., L.R.C.P., Chief Demonstrator of Anatomy, Mason University College, Birmingham, proposed by B. C. H. Windle, F. G. Parsons, A. Keith. H. M. RIGBY, M.B., Assistant Demonstrator of Anatomy, London Hospital Medical College, E., proposed by T. Openshaw, A. Keith, C. B. Lockwood.

Adrenal Structures from the Inguinal Canal.

Mr C. B. LOCKWOOD showed sections and micro-photographs of a fatty tumour which he had removed from the inguinal canal of a young man. The tumour was composed of a number of lobules, each of which had the typical structure of an adrenal body. The development of the adrenals and epididymis from the Wolffian body was

discussed, and the origin of their bodies was attributed to Wolffian remains.

This communication will be printed in full, with micro-photographs, in the next number of the *Journal of Anatomy and Physiology*.

Mr F. G. PARSONS showed a *Liver*, removed from the post-mortem room at St Thomas's Hospital, in which the upper surface showed a deep transverse and three antero-posterior fissures. On the under surface the Spigelian lobe was reduced to the size of a large nut, and the caudate lobe somewhat enlarged. There were signs of old inflammation on the surface of the organ, and the fissures were looked on as the result of cicatricial contraction.

Mr N. BISHOP HARMAN, M.B., exhibited the cast of a *Liver* showing curious hour-glass constriction of the left lobe, which is also abnormally

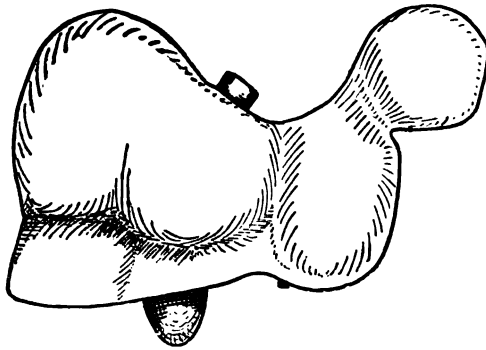


FIG. 1.

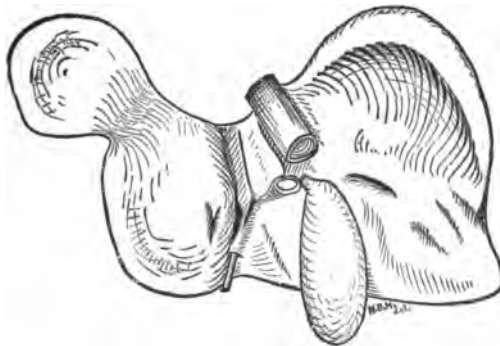


FIG. 2.

long, (figs. 1 and 2). Taken some time ago from a dissecting-room specimen. The subject was an old man, with a strong alcoholic history.

The cast shows that the liver had retained most definite markings, which, since it was taken without special hardening, argues that its consistency was greater than normal. Numerous sulci on its surfaces, especially the long furrow on its anterior surface, skirting the anterior border, and the small size of the organ, all point to a condition of cirrhosis, to which pathological change the extraordinary length and shape of the left lobe must be ascribed.

Mr CECIL H. LEAF brought before the meeting several specimens of *Liver*, hardened *in situ*, showing a linguiform projection of the right margin in the neighbourhood of the 10th costal cartilage, which had come to be known by the name of Riedel's lobe. It was not a lobe in the true meaning of the term. Pronounced specimens, such as that shown in fig. 3, were not common, but were of great clinical interest, as they were frequently mistaken for tumours or floating kidneys. The photograph was taken from a female subject of middle age. The process in this case was limited in front by the sulcus for the gall-bladder. The kidney, as may be seen from the figure, was depressed, so that its lower end lay normally in the iliac fossa. The process extended downwards almost as far as the kidney, and covered that organ in front. In this case there was marked evidence of tight-lacing, and such marked cases are almost entirely confined to women. Yet Professor Riedel (*Erfahrungen über die Gallenstein Krankheit*, Berlin, 1892) and Professor Arthur Thomson (*Journ. of Anat. and Phys.*, 1885, vol. xix. pt. iii.) did not find evidence of this as a cause in their specimens. But undoubtedly many of the cases, especially those of a high degree, were caused by undue compression, as might be seen from the shape of the organs hardened *in situ*, and also from the fact that these processes were much more common in women than in men. As far as he knew, they had not been recorded as occurring in children. Riedel found a very high percentage of cases accompanied by stones in the gall-bladder, and concluded that this was the most common cause. In none of the cases shown were gall-stones present.

A less degree of development is frequently met with. It occurs, probably, in over 35 per cent. of women who have passed middle age. It does not occur in men with half that frequency.

Mr Leaf also showed specimens, mostly from the bodies of women, in which the organs had been hardened *in situ*, with the spleen well overlapped by the left lobe of the liver. In such cases it would have been impossible to separate the splenic from the hepatic dulness clinically. Ballantyne and Symington had drawn attention to this condition, especially as a normal condition in childhood, but he did not think physicians were aware of its frequent occurrence in adults, especially women. This also is very possibly an effect of tight-lacing.

Mr Leaf pointed out the frequent occurrence of an exaggerated condition of the caudate lobe of the human liver, and specimens lent by Mr Keith were shown demonstrating the great size of this lobe in New and Old World monkeys, and its gradual diminution in the series of anthropoids.

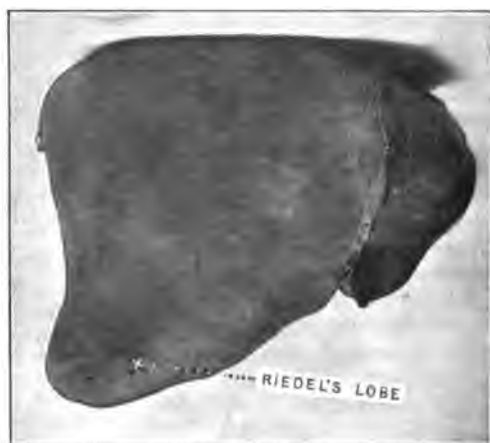


FIG. 3.

Mr J. H. WARING exhibited a specimen in which the *cystic and hepatic ducts* joined so close to the duodenum that a common bile duct could scarcely be said to exist.

Mr R. H. BURNB, B.A., Assistant in the Museum of the Royal College of Surgeons of England, read a paper, illustrated by specimens and drawings, on the *Bile Ducts of the Common Otter (Lutra vulgaris)*.

The liver of the otter conforms in its general features to the usual carnivore type, with the lobes sharply divided from one another, and separate far up towards the base, the caudate lobe very large (it is larger in the otter than in the other carnivores that I have examined), and the Spigelian lobe well marked and elongated.

The bile ducts, however, present a most curious arrangement (fig. 4), and one that seems to be very uncommon, if not absolutely unique, among mammals, and that apparently finds its nearest parallel in the biliary network of the reptile.

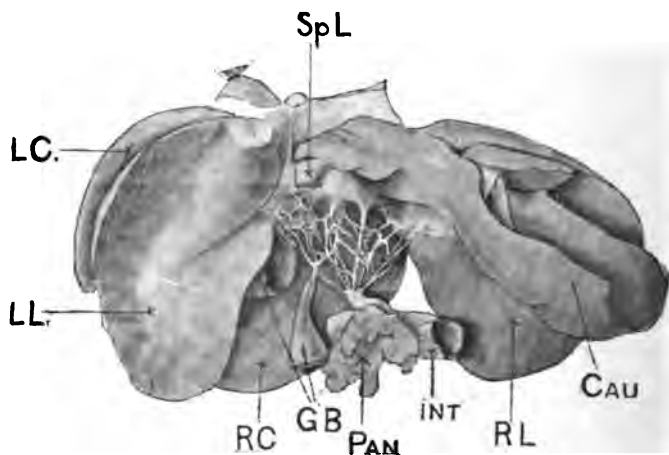


FIG. 4.—Liver of an Adult Female Otter (*Lutra vulgaris*),¹ seen from the postero-dorsal aspect. The gall-bladder has been divided and displaced, and the greater part of the Spigelian lobe removed to show more clearly the underlying network of hepatic ducts.

Reference letters:—*Ca.*, caudate lobe; *G.B.*, gall-bladder; *int.*, intestine; *L.C.*, left central lobe; *L.L.*, left lateral lobe; *Pan.*, pancreas; *R.C.*, right central lobe; *R.L.*, right lateral lobe; *Sp.L.*, Spigelian lobe.

After considerable search, I have been able to find only two descriptions of this remarkable condition, both of which are without illustration, and, from their age, liable to be overlooked: the first is by Lorenzini,² published as long ago as 1678, and the second—in Italian—by Alessandrini in 1838.³

¹ No. 807 Q.a, Physiol. Ser., Royal College of Surgeons Museum, dissected by the Prosector (Mr William Pearson).

² Lorenzini, "Ductus cholidochus Lutreæ," *Ephemer. Acad. Nat. Cur.*, 1678-79, vol. x. p. 405.

³ Alessandrini, "Nota sulla disposizione dei condotti biliferi del fegato della Lutra," *Nuov. Ann. d. Scienze Natur.*, i., 1838, p. 254.

An examination of the liver from its postero-dorsal aspect (fig. p. xx) shows the large pyriform gall-bladder imbedded as usual in the right central lobe. Its narrower end, at the point at which it would naturally pass into the cystic duct, bifurcates, and the two resulting ducts shortly again divide, and take part in a general network formed by the hepatic ducts. The hepatic ducts are twenty or more in number; they emerge from the bases of the liver lobes, and in their passage towards the intestine converge and freely anastomose both with one another and with the above-mentioned branching ducts from the gall-bladder. Upon nearing the intestine, the anastomoses become less frequent and finally cease, leaving seven independent ducts, which, after a short course, open upon the apex of a stout common bile duct that projects, wart-like, from the wall of the intestine. This duct also receives that of the pancreas at a point close to the intestinal wall.

A somewhat similar network to this of the otter, but formed mainly from the cystic ducts, is found very generally among snakes, and an indication of it is to be seen in crocodiles; but we meet with its most striking parallel in the combined cystic and hepatic network of a lizard (*Varanus salvator*) described by Beddard in 1888.¹

Mr A. KEITH read a short paper, illustrated by drawings, on *the Position and Manner of Fixation of the Liver of Primates, and the part these factors played in the Lobulation of the Liver*. He held that the consolidation and absence of fissures in the human and anthropoid liver was the result of their upright posture. When the viscera were removed from the abdomen of a pronograde monkey, such as the macaque or baboon, the attachment of the dorsal mesentery was found to form an almost straight median dorsal line. The liver was attached to the diaphragm by a reflection of peritoneum over the inferior vena cava, but this area was of relatively small size, and a right lateral ligament existed to a limited extent only. In the anthropoids, in all of which the body is held in an erect position during locomotion, the dorsal mesentery had acquired all the complicated attachment seen in man. The viscera of the abdomen were thus much more firmly and extensively fixed to the posterior wall than in pronograde monkeys. The caval attachment to the diaphragm and the right lateral ligament were much more extensive. The liver no longer rested for support on the anterior abdominal wall. This more extensive fixation of the liver to the posterior abdominal wall in anthropoids was evidently accompanied by the disappearance of the deep fissures of the liver. These fissures had persisted to a greater extent in the gorilla than in any other anthropoid. The lobes of the liver in pronograde animals moved on each other, accommodating themselves to the other viscera of the abdomen during descent of the diaphragm in inspiration.

Another observation which had not been previously made was, that

¹ Beddard, "On certain points in the visceral anatomy of the Lacertilia, particularly of Monitor," *Proc. Zool. Soc.*, 1883, p. 105. This network is much less complicated than in Beddard's instance, in a specimen of *V. salvator* in the Royal College of Surgeons Museum, No. 802, B.b.

not only did the thorax become wide at the expense of its antero-posterior diameter in the anthropoids, thus leading to a change in the shape of the thoracic viscera, but the abdominal cavity had also shared in the alteration, with the result that the shapes of many of the abdominal viscera underwent a modification. The liver of the anthropoids is human in shape, its transverse diameter, as a rule, being greater than its antero-posterior; whereas the liver of pronograde animals was cordiform, with its greatest diameter from back to front.

Prof. ARTHUR THOMSON then read a paper on *the Morphological Significance of certain Fissures in the Human Liver*. (This paper will appear *in extenso* in the *Journal of Anatomy and Physiology*.) After referring to the frequent occurrence in adult human livers of clefts and fissures, of varying depth and position, he proceeded to describe the appearances met with in the foetal condition. His observations had led him to believe that these fissures, which occur in more pronounced form in the foetus, are the survival of a condition in which the liver is further subdivided. With the intention of testing the accuracy of this view, he had made an inquiry into the arrangement of the lobes and fissures in the livers of the anthropoid apes, and found evidence confirmatory of this opinion. He traced the gradual process of fusion which occurs between the lobes in apes, and was able to demonstrate that the 'anomalous' fissures met with in man, and seen in most pronounced form in the foetus, were the survivals of the caudate fissures, and the fissures subdividing the right lobe characteristic of lower forms. Professor Thomson exhibited a number of specimens illustrating these various points, and referred especially to two foetal livers, each of which possessed a separate caudate lobe, such as is characteristic of the anthropoids. He also emphasised the fact that the Spigelian and caudate lobes are of proportionately greater size in the foetus than in the adult.

Mr N. BISHOP HARMAN exhibited a specimen from the Cambridge Dissecting-Room, showing *anomalous Nerve Supply to the Leg* (fig. 5). The case was mentioned in "Notes and Queries," No. 16, *Jour. of Anat. and Phys.*, Jan. 1899. The arrangement found differs from the normal in—

1. The absence of—
 - a. The musculo-cutaneous nerve.
 - b. The branches of the anterior tibial nerve, which should supply—(1) M. extensor brevis digitorum. (2) Dorsal carpal joint. (3) Skin of cleft of toes I and II.
2. The increase of—
 - a. The internal saphenous nerve, to supply toe I and tibial side of toe II.
 - b. The external saphenous nerve, to supply skin of clefts of toes II, III, IV, and V, and fibular side of toe V. Also to supply the diminished extensor brevis digitorum muscle, which has only two tendons, to toes III and IV.

The external saphenous nerve is of large size, and composed of communicans tibialis and communicans fibularis, in the proportions of about one to three.

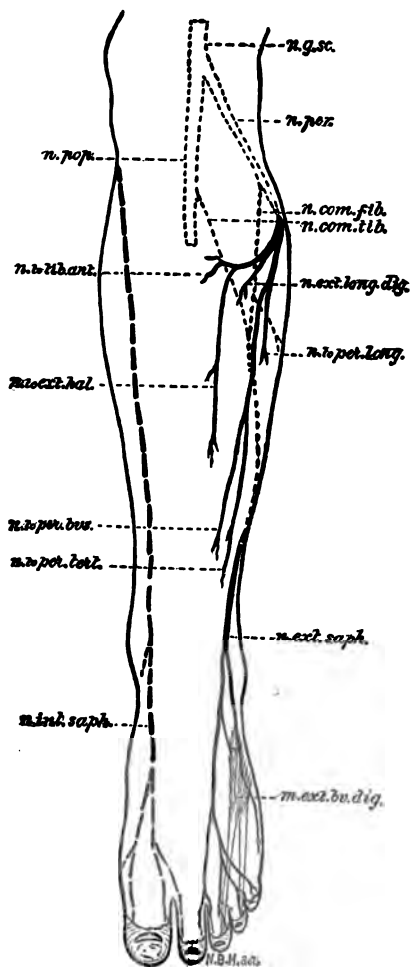


FIG. 5.

The dissection had advanced too far at the time of discovery to allow of tracing the origin of the nerves to the plexus roots.

As far as can be ascertained, no such condition has been recorded before. The varieties described by Quain and Krause do not hint at such a variation. In the Report of the Collective Investigation Committee on the skin supply of the foot (*Jour. of Anat. and Phys.*, 1891,

vol. xxvi.), replacement of the anterior tibial supply by an enlarged internal saphenous nerve was found in one case only out of 229, but the musculo-cutaneous was present in this and all other cases. [In the *Journal of Anatomy*, vol. vi., p. 105, W. Turner refers to cases in which the external saphenous nerve supplied the skin on the dorsum of the 3rd, 4th, and 5th toes.]

Whether this be merely a case of the transference of nerve paths, the axons usually passing by the musculo and cutaneous travelling by the external saphenous, and those of the dorsal anterior-tibial by way of the ventral internal saphenous, or whether there is at the same time a partial loss of axons, as is suggested by the smallness of the extensor brevis digitorum muscle and the absence of a dorsal carpal branch, is a point of interest.

Dr BARCLAY SMITH exhibited a case of *divided Parietal Bone in a Skull*, from the Egyptian Collection in the Anatomical Museum at Cambridge. The anomalous suture crossed the bone diagonally, from the lambda to the pterion, thus dividing it into two triangular pieces. One of the interesting features of the case was the change which the suture underwent at the point where it crossed the temporal crest, being dentate and lambdoidal in character in its posterior half, while anteriorly it simulated the squamo-parietal suture. The skull was asymmetrical, and its maximum breadth was at a level considerably below that of the temporal crest; there was a decided bulge in this region on the left side. On neither side could a definite parietal eminence be said to exist.

A photograph was shown of a case of *post-anal Gut in a foetal Pig*, sent for exhibition by Mr C. F. W. M'Clure, Princeton University.

PROCEEDINGS OF THE
ANATOMICAL SOCIETY OF GREAT BRITAIN
AND IRELAND.

APRIL 1899.

AN Ordinary Meeting of the Society was held on Friday, April 28th, at 4 P.M., at Middlesex Hospital Medical College. Professor ALEXANDER MACALISTER, F.R.S., the President, was in the chair. Nineteen members and one visitor were present.

The minutes of last meeting were read and confirmed.

The following gentlemen were elected members of the Society :—

Mr ARTHUR EDMUNDS, B.Sc., Demonstrator of Anatomy, King's College, London, proposed by A. W. Hughes, F. G. Parsons, A. Keith. Mr D. J. ARMOUR, B.A., M.B., M.R.C.P., Demonstrator of Anatomy, University College, London, proposed by G. D. Thane, Percy Fleming, G. P. M. White.

Professor A. FRANCIS DIXON exhibited a *Stomach* taken from an adult male subject, which had been hardened by injections of formalin. The stomach presented a remarkable shape, as one portion was much constricted and somewhat cylindrical, while the rest of the organ was considerably dilated. The constricted portion of the stomach was towards the pyloric end, and lay behind a V-shaped loop of transverse colon, which in this subject was bent upwards towards the liver. The dilated portion contained much milky food material, and lay chiefly in the left hypochondrium. It was in contact with the anterior abdominal wall on a triangular area. Owing to the interposition of the loop of transverse colon, only a relatively small portion of the stomach was in contact with the under aspect of the liver. As all the abdominal viscera appeared to be healthy, the condition present might be taken to represent a possible normal temporary form of the stomach.

Specimens of *abnormal Stomachs* were also shown by Dr ARTHUR ROBINSON and Dr T. H. BRYCE. A description of Dr Bryce's specimen will be found in his paper on *A Duodenum showing an Abnormal Flexure*, on page xxviii.

Professor ARTHUR THOMSON exhibited a model to demonstrate his views with regard to the production of natural curliness in the hair. He pointed out that in the consideration of this question we have to take into consideration three factors : 1, the hair shaft and follicle ; 2, the hair muscles ; and 3, the sebaceous gland.

Straight hair is always circular on section, dense in structure, and usually thicker than curly or frizzy hair, which is compressed and flattened, and usually fine. In order that the muscles may act as an erector of the hair it is requisite that the shaft of the hair embedded in the skin should be sufficiently strong to resist any tendency to bend ; unless this be so, the lever-like action necessary to produce its erection is destroyed. When the hair is fine and ribbon-like the shaft is not sufficiently stout to resist the strain of the muscle, and hence assumes a curve, the degree of curvature depending on the development of the muscle, the resistance of the hair, and the size of the sebaceous gland, which, according to Professor Thomson's observation, is usually larger in races with frizzy hair. The curvature thus produced becomes permanent, and affects the form of the follicle in which the hair is developed ; the softer cells at the root of the hair have to accommodate themselves to this curve, and becoming more horny as they advance to the surface, naturally retain the form of the follicle, the cells of the concave side of the hair being more compressed than those on the convex side. In this way, he believed, we have an explanation how the curvature of the follicle is produced, and how the hair retains the form of the follicle after it has escaped from it. A more detailed account of Professor Thomson's views will shortly be published.

Drs R. J. A. BERRY and JOHN CRAWFORD then read a short paper, illustrated by stereoscopic views, on *the Stomach and Pylorus*. After pointing out the methods employed and the objects of the research, the authors proceeded to state that, in their opinion, the greater curvature was only three times as long as the lesser, and not four or five, as more generally believed. After referring briefly to the other dimensions of the stomach, and the influence of age and sex on these dimensions, the authors demonstrated the existence of a cardiac valve, and stated that they believed the valve to be an actually functional valve, giving their reasons for the view adopted. Referring next to the pylorus, the authors pointed out that the pyloric orifice was almost always oval, and very seldom circular ; the dimensions of the aperture were pointed out and contrasted with the results obtained by other observers ; while, lastly, they stated that they differed from the previously recorded results as regards the direction of the longest axis of the pyloric aperture, inasmuch as they regarded the direction of that axis from above downwards and backwards as

being the normal one. A reference to some of the more rare forms of pyloric openings which they had met with concluded the paper. This paper will appear *in extenso* in the *Journal of Anatomy and Physiology*.

The Calcar Avis in the Mammalian Brain.

Dr G. ELLIOT SMITH, in this communication, adduced evidence to show that a representative of the true calcarine sulcus (the "anterior calcarine fissure" of Cunningham) is present as the retro-spherical portion of the "fissura splenialis" of Krueg in the Marsupialia, Chiroptera, Edentata, Cetacea, and the great collection of ungulate and unguliculate mammals. The calcarine sulcus is therefore the common property of the mammalia, rather than a distinctive feature of the primates. As in many mammals (such as *Thylacinus*, *Pteropus*, *Orycteropus*, *Cholæpus*, *Phoca*, among many others) the representative of the calcarine sulcus is "complete," a homologue of the *calcar avis* is consequently found in the lateral ventricle. The term "calcarine sulcus" he proposed to apply exclusively to the "anterior calcarine fissure" of Cunningham, and the "posterior calcarine fissure" the "post-calcarine sulcus." The reason for this distinction is briefly that the latter is not a causal factor in the production of the *calcar*, but is placed mainly, and generally wholly, on the caudal side of the true calcarine sulcus. The two furrows are of vastly different morphological values, the calcarine being a phylogenetically old and most constant feature, while the post-calcarine is recent and much more variable.

A historical and critical account of the views of Vicq d'Azyr, Cruviellier, Gratiolet, Bischoff, Serres, Owen, Huxley, Turner, Flower, Murie, Meynert, Pansch, Krueg, Cunningham, Ziehen, Benedikt, Retzius, and Fish, among many others, was given, and the relations of the rhinal, collateral calcarine, retro-calcarine, occipito-parietal, and sub-parietal sulci were discussed.

A Rare Abnormality in the Curvature of the Duodenum.

By THOMAS H. BRYCE, M.A., M.B., F.R.S.E.

In position and curvature the duodenum is, within certain narrow limits, remarkably constant. The variations recognised are those in which the shape varies, within normal limits, between the primitive ring-shaped form on the one hand, and the V-shaped form on the other. Schiefferdecker¹ has described two cases of remarkable coiled conditions of the first part of the intestine, in which the duodenum and the first portion of the jejunum, which had also lost its mesentery, were involved; and Harman² has lately recorded two instances of a somewhat similar nature. In one of his cases the duodenum was normally placed, but in the other it was disposed in a double coil. Dwight,³ in a paper on the duodenum, refers to certain instances in

¹ *Archiv. für Anatomie*, 1886.

² *Jour. Anat. and Phys.*, vol. xxxii.

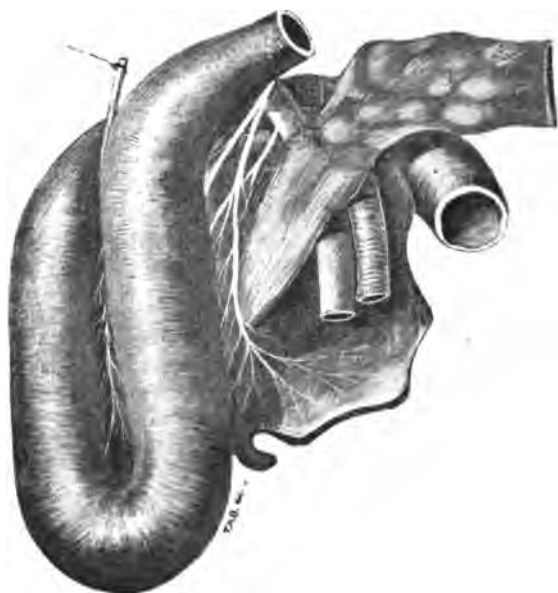
³ *Journ. Anat. and Phys.*, vol. xxxi.

which the terminal part of the tube formed a coil over the left kidney, so that it had the shape of an S placed on its side. The case I have to record belongs, however, to a somewhat different category from these. It is merely an unusual variety of the V-shaped form, in which the limbs of the loop have been displaced.

The specimen was obtained from a male subject aged 48. Besides the abnormal duodenum, there was a well marked bilocular stomach, which I shall first describe.

The stomach was divided into two chambers, a smaller pyloric and a larger cardiac, by a constriction which measured 8 cm. in circumference when the viscus was distended, and was placed about the middle point of the lesser curvature, being 9 cm. from the pyloric and 8 cm. from the cardiac end. There was a slight twist, or rather a torsion, round the longitudinal axis at the point of constriction, the pyloric chamber being somewhat tilted forwards. There was no annular thickening at the isthmus, nor anything in the way of a sphincter, but the three muscular layers were all thicker than over the rest of the viscus, and the longitudinal fibres on the lesser curvature were prolonged obliquely on the anterior surface of the constricted part to the greater curvature, forming an external oblique layer. When the abdomen was opened, the stomach was found slightly distended, and as the liver was fixed *in situ*, there were well marked facets, indicating the relations of the stomach to that organ. The pyloric chamber was in contact by its anterior surface with the greater part of the under aspect of the left lobe. The large concave facet corresponding to it was bounded behind by a rounded ridge, running from the transverse fissure to the left border, and behind this was a surface directed backwards, impressed by the cardiac end of the greater sac. The ridge lay on the omentum, and intervened between the chambers, while the left border exactly corresponded with the isthmus between them, projecting downwards wedge-like into the constriction. The pylorus lay close to the anterior border of the liver, on which there was a ridge corresponding to it on the under surface of the left lobe, situated some distance from the longitudinal fissure, between the impressions for the stomach and the duodenum. From this point the duodenum extended to the right in a gentle curve downwards and outwards in contact with a facet on the under surface of the liver, close to the anterior border, first on the left lobe and then on the quadrate globe, till it reached the gall-bladder. It then curved sharply and assumed a vertical direction, lost its peritoneal investment, and passing behind the transverse mesocolon, extended to the level of the 4th lumbar vertebra. Here it turned in an acute curve backwards and slightly to the right, and ascended again in contact with the descending limb of the loop. It lay on the psoas muscle (ureter and spermatic vein intervening), then on the lower half of the inner border of the right kidney, and on the right renal vein. As it ascended, it gradually tended towards the middle line, till it got directly behind the descending limb, on a level with the 2nd lumbar vertebra, and a little below the plane of the pylorus. Here the tube assumed a transverse direction, and crossed, with a distinct anterior

convexity, over the inferior vena cava, right crus, and aorta, just below the origin of the superior mesenteric artery, then passing behind the upper part of the head of the pancreas, it turned forwards and to the left to the duodeno-jejunal junction, carrying off with it a peritoneal investment from the lower layer of the transverse mesocolon. The vena portæ and the common bile-duct passed between the anterior and the posterior transverse portions, and the bile-duct opened with the pancreatic duct into the duodenum, on the posterior aspect, of the descending limb slightly to the inner of the middle line at a point 8 cm. from the pylorus. The head of the pancreas lay



Dr Bryce's case of abnormal flexure of duodenum. Explanation in the text.

entirely to the left of the loop, its edge being received between its two limbs; the upper portion of the head and the neck of the gland were anterior to the terminal transverse section. The outer and upper border of the ascending limb was in contact with the ridge bounding the facet on the liver for right kidney.

The suspensory ligament was a broad band descending from the right crus and fascia over the aorta to the terminal transverse part of the tube; no muscular fibres could be demonstrated in it.

The first part of the tube had a complete peritoneal covering, and the gastro-hepatic omentum was continued out along its upper border as far as the first flexure. For a short distance below this the outer and anterior surfaces were alone covered, the inner and posterior surfaces being denuded of their covering; then the tube passed behind

the mesocolon and lay entirely behind the peritoneum, till it emerged at the duodeno-jejunal junction on the left side of the second lumbar vertebra. The terminal portion was, of course, quite separated from the peritoneum by the pancreas. There was no duodenal fold nor duodeno-jejunal pouch.

No abnormality was noticed in the disposition of the colon or its peritoneal attachments.

The duodenum measured from the pylorus to the duodeno-jejunal junction 32 cm., 2 cm. in excess of the normal maximum, as given by Professor Symington in *Quain's Anatomy*.

No very apparent explanation for this abnormal position of the duodenum is forthcoming. There is no evidence of abnormal peritoneal traction, by adhesion or otherwise, having been in operation. The slightly excessive length of the tube is not sufficient to explain the displacement of the limb of the loop, and the condition of the stomach does not suggest any obvious causal relation. The condition must have arisen after the terminal part of the tube was fixed at the neck of the primitive mesentery, but before it lost its meso-duodenum. If one takes a loop of tubing fixed at both ends, and twists one end through a half-circle, the limbs of the loop will assume the position of the two limbs of this duodenum; and one may imagine some such torsion to have taken place, though I can make no conjecture as to its cause. On the other hand, Mr W. J. Young¹ has pointed out that there is a normal twist in the duodenum, such that the lesser curvature of the stomach is continuous with its uncial border. This apparently takes place in the opposite direction from the twist I refer to, and it is just possible that we have to deal with a condition expressive of a failure of this normal twist. The relations of the curvatures of the stomach to the borders of the duodenum rather tend to support this idea, and the marked constriction in the stomach might then be causally related to the condition.

Professor A. FRANCIS DIXON read a paper on *the form of the empty Bladder*, and also drew attention to the arrangement of the peritoneum in connection with the empty organ. Reasons were advanced for considering the recto-vesical ligaments to be connections of the vasa deferentia rather than of the bladder, and to be the representatives of the utero-sacral ligaments of the female. The plica vesicalis transversa was shown to have its origin at an early period in foetal development, namely, at the time when the inguinal pouches of the peritoneum arise. The origin of the fold was considered to be dependent on the formation of these pouches.

¹ Proc. Anat. Soc., Feby. 1898, *Journ. Anat. and Phys.*, vol. xxxii.



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